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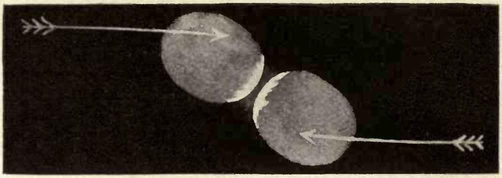

Fig. 1.—Pair of Stars Distorted and Coming into Impact.

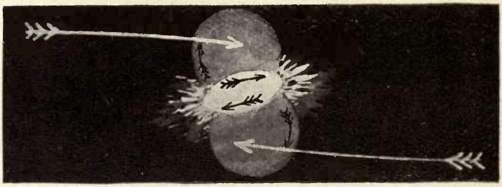

Fig. 2.—Pair of Stars in Impact.

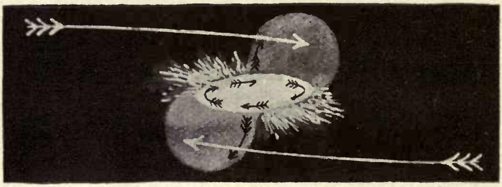

Fig. 3.—Stars Passing out of Impact, and Formation of Third Body.

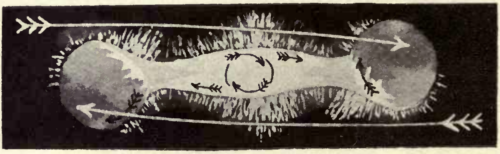

Fig. 4.—Showing Entanglement of Matter in each Body.

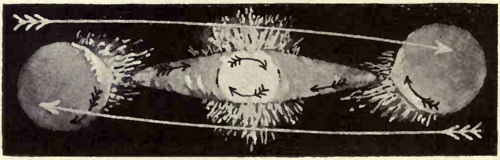

Fig. 5.—Two Variables and a Temporary Star.

Frontispiece.

THE BIRTH OF WORLDS AND SYSTEMS

BY

PROFESSOR
A. W. BICKERTON

HARPER & BROTHERS
LONDON & NEW YORK

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AUTHOR OF

"A NEW STORY OF THE STARS"
"THE ROMANCE OF THE EARTH"
"THE ROMANCE OF THE HEAVENS"
ETC.

WITH A PREFACE BY

PROFESSOR ERNEST RUTHERFORD, F.R.S.

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PREFACE

I HAVE been asked to write a few words of introduction to this volume by my former teacher, A. W. Bickerton, for many years Professor of Physics and Chemistry in Canterbury College, University of New Zealand. I do so from the personal rather than the scientific standpoint, for I can lay no claim to be regarded in any way as an authority on astronomical matters, although, I trust, I take that intelligent interest in the subject which is possible for one who is a specialist in another branch of science.

More than thirty years ago Professor Bickerton published in the New Zealand Philosophical Institute a theory to account for the origin and life history of new stars. These stars suddenly appear in the heavens, increase in brilliancy for some time, and then in the course of a few months or years disappear from view. It is now thought by many that the birth of new stars must be due to some kind of impact between two celestial bodies. This point of view was taken thirty years ago by Professor Bickerton. He concluded that when such impacts took place, the majority

of them would be grazing or partial. The central point of his theory lies in the deduction that in many cases a third and intensely heated body will be formed as the result of such partial impacts. No doubt, it is difficult to predict with certainty the exact consequences of such collisions, but the formation of a third body has always appeared to me as highly probable. Accepting this view, many of the conclusions put forward by the author follow as natural deductions. In many cases, the third body is at such a high temperature that the light elements are able to escape from it, and a spherical shell of intensely heated gaseous matter travels outward at great speed.

Professor Bickerton develops with much force and originality the consequences of this theory, and considers that it offers a reasonable and satisfactory explanation, not only of the origin, but also of the variations in brilliancy, and in the type of spectra given by new stars.

Before any theory can be accepted, it is necessary to examine in great detail how far it offers a reasonable explanation of experimental facts. As far as I know, this has not so far been done except in a general way, with regard to the theory of Professor Bickerton. A large amount of spectroscopic data has now been accumulated in connection with new stars, and it would be of interest to examine carefully how far the theory is able

to explain the facts. In any case, the theory should serve as a valuable working hypothesis to those who are engaged in interpreting the spectroscopic evidence afforded by new stars.

In later chapters Professor Bickerton applies the general theory in an attempt to explain the origin and character not only of our solar system, but of the universe as a whole. His theories are highly ingenious and interesting, but, as he expressly states, they are to be regarded as speculations rather than logical deductions of his theory. No doubt there will be much difference of opinion in regard to the validity of such speculations.

Professor Bickerton writes in a clear and vigorous style, and I am sure that the general reader, whatever may be his scientific opinions, will find in this volume much that is interesting and stimulating.

E. RUTHERFORD.

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The following Early papers by Professor A. W. Bickerton on Construction Collision, are to be found in the Transactions of the N.Z. Institute.

On Temporary and Variable Stars. July 4th, 1878.

On Partial Impact, &c. August 1st, 1878.

On the Visible Universe. February 13th, 1878.

On the General Problem of Stellar Collision. March 13th, 1879.

Presidential Address on the Genesis of Worlds and Systems. April 3rd, 1879.

Causes tending to alter Eccentricity of Planetary Orbits. May 6th, 1880.

On the Origin of the Solar System. August 5th, 1880.

The Origin of Double Stars. August 5th, 1880.

Some recent evidence in favour of Impact. November 1st, 1893.

The Immortality of the Cosmos. November 7th, 1894.

Synoptic Statement of the Principles and Phenomena of Cosmic Impact. Prepared for the criticism of Scientific Men and Societies. November 7th, 1894.

1 Leinster Gardens, W. 1911.

THE BIRTH OF WORLDS AND SYSTEMS

CHAPTER I

INTRODUCTORY SKETCH OF PARTIAL IMPACT

IN 1878 I had been devoting a good deal of time to the study of heat, especially celestial thermodynamics, and was struck with the singularly insufficient suggestions made to account for the amazing phenomena known as temporary stars, apparitions that blaze forth in the heavens, that grow in intensity until they are often scores of thousands of times the brilliancy of our Sun, and then gradually fade until they are invisible to the naked eye.

I had studied under Tyndall, and his lectures and books had made the thought of the amazing store of energy in the Sun very familiar to me. I knew that no theory of combustion could account for his stupendous energy; much less would it account for the sudden manifestation of many thousands of times the Sun's intensity. Hence it follows that the suggestion, that the

phenomenon was an outburst of burning hydrogen, was puerile. Tyndall had impressed upon his students what a vast store of energy a mass of matter weighing so little as a pound at the surface of the Earth would convert into heat, if it should fall into the Sun. It would acquire a speed of much over 300 miles a second, whilst a mass with the velocity of 300 feet a second has an onward motion kinetically equivalent to the same mass of water heated 1 degree centigrade. There are 5280 feet in a mile, and the relative energy is as the square of the velocity. That is to say, the mass of a gramme falling into the Sun would develop more than 27,000,000 calories. Now dynamite has an energy of about 1000 calories, so that a body falling into the Sun would cause an explosion over twenty-seven thousand times as violent as that of the same mass of dynamite. A pair of dead suns, that is to say two dark stars, colliding would possess energy sufficient, if suddenly converted into heat, to account for the phenomena of temporary stars. All suns possess proper motion. Hence it was evident that the orbits of two suns in approaching one another would be similar to that of an ordinary errant comet. There would be mutual deflection and mutual distortion, and it would be extremely improbable that the suns should meet centre to centre. Much more frequently there would be partial impact or grazing collision; therefore,

the problem to be considered was, what would happen were a pair of dead suns to graze? Before devoting myself to pure science I had studied as an engineer, and had been offered a professorship of engineering, so that the phenomena of impact were very familiar to me. I knew that, with such velocities as those generated by colliding suns, the hardest substance was almost infinitely soft, and the idea that a grazing impact would arrest the onward motion of the stars never once occurred to me. The portion of each body actually in the path of the other would be torn from the main portion, and these torn-off portions would coalesce into a new or third body, explosively hot and of surpassing brilliancy.

The two diminished suns would pass on, each with a fiery scar where it had been cut. Each would be set rotating, and each would be like a policeman's lantern hung by a string and set spinning. Each would present alternately its bright and dark face to any point on its equatorial plane. They would be a pair of celestial searchlights, that would send the flash of their amazing beams through the length and depth of the universe, and to our observation on earth shine as variable stars.

See Frontispiece.

In fig. 1, you see the tidal distortion of the approaching suns; in fig. 2, you see the flash of the collision, and the third body forming; in fig.

3, the spindle-shaped third body is formed, and the two suns, or stars, are passing on; in fig. 4, you see that a considerable mass of the third body adheres to the two retreating suns; whilst in fig. 5, the third body is completely detached, and the two torn suns have recovered their sphericity, and are sending the beams of their revolving searchlights throughout the universe as they shine as variable stars. At the same time you see the central body has grown larger, the whole series representing about two of the birth hours of a new star of vast brilliancy.

The formation of this explosively hot third body, was the fundamental thought that for over thirty years has been growing and illuminating the fields of celestial dynamics in every direction.

It has sent its rays into many obscure places in the science of astronomy, often showing up every detail with pellucid clearness. This first glance at the problems of grazing suns discloses to our mental gaze the sudden birth of a temporary star of amazing brilliancy, and when not too distant from us to be seen, of a pair of variable stars also. Such were the first clear and apparently indisputable dynamical deductions that grew out of the induction, that the flash of light called a new star might be produced by the grazing of a pair of suns.

I little thought at first to what a distance so simple an idea would lead one, and of the

mass of complexities that lay immediately in the way. In connection with this third body, came the questions of the specific heat of different elements, of the varying momenta of the different depths of graze, questions of atomic velocity and of atomic energy ; questions of the gravitating power of the explosively hot giant spark ; all kinds of thermodynamic ideas ; also questions of kinematics and kinetics.

In the torn suns we were faced with considerations such as the struggle between the new impressed rotation and the original rotation ; the pulsations produced by the filling-up of the deep, long valleys cut by the other one around each of the torn suns ; the exposure of the hot interior ; the stupendous gravitational energy forcing up the interior matter, its overfilling and sinking back again.

Returning to the central body, which the two retreating torn suns were leaving behind between them, one saw that, at the impact, the different elements would be given a temperature that would be proportional to their atomic weight. Oxygen would be sixteen times as hot as hydrogen, lead two hundred and seven times as hot as hydrogen, each and every one of these elements moving at velocities of hundreds of miles a second, yet all would be tending towards an equality of temperature, as, for example, the hot lead would be robbed of its high temperature by the com-

paratively cooler hydrogen. Then, when something like a balance or equality was gained, the energy of unit mass of each element would tend to be inversely as the atomic weight, hydrogen having four times the power of escape of helium, sixteen times that of oxygen, and two hundred and seven times that of lead.

Their velocities would tend to follow the law of Graham, and a kind of atom-sorting would ensue, to which the term "Molecular Selective Escape" was applied. This atom-sorting* tells us that the new-born star would soon consist of a brilliant nucleus of heavy elements surrounded with a set of ensphering shells of different gases; the lightest, viz. hydrogen, being on the outside, and if, as I then thought, there were elements lighter than hydrogen, these super-light elements would take precedence of escape, and be on the outside of the hydrogen shells.

The question then occurred, were there such shells? I did not know, for although I held South Kensington teaching certificates in thirteen branches of science, I knew but little of Astronomy, so I had to study the subject. I found that Herschel had stated that there were such shells,

* In these papers in almost all cases it is assumed that compound and polyatomic molecules are dissociated into monatomic molecules; molecule and atom are then the same. The terms are often used indiscriminately in this volume, unless polyatomic molecules are especially being considered.

which he called Planetary Nebulæ. It was over a score of years before I knew they were sphere within sphere, as the varying velocity of the elements had caused me to picture the shells as being.

The mind then returned to the dense nucleus. Clearly it would be rotating, hence the outward rush would not finish with the particles coming to rest; the motion would end in a curve, and all that mass of heavy elements would form a revolving meteoric swarm, which, if the colliding bodies were small, would be a comet. If, on the other hand, it were very large, the swarm might develop into a star cluster, which in turn might become a sun surrounded with countless satellites, a nebulous star. Soon after impact the swarms might become entangled with the variable stars, and might produce the nebulosity at minimum, so characteristic of these bodies. These variable stars should sometimes be in pairs; yet no book told us they were so. On plotting the then known variables, we found so many in pairs that a statistical mathematician told us there was only one chance in 167 millions of billions of trillions that there was not some law connecting them, and we have never heard of any other suggestion, than that the connecting law was impact. A little later on, we saw that this new third body would exercise a retarding influence on the two escaping torn suns, and ought often to wed them into double

stars. Then all the details of the formation of the permanent orbit were thought out; but it was clear that if this were their origin, recently wedded doubles should be doubly variable, and older wedded couples should be singly variable; whilst the majority would be so old as to have lost all variability; but no standard book of the time said anything about such variability. After looking out for a year or so, we found that the great Struvé had shown that twenty-three double stars were variable, and he suspected forty more. Recently the improved power of the telecamera has given us spectrograms of several doubles in which both constituents actually are variable, a piece of evidence more convincing still than that of the pairing of variables. This one fact proves conclusively that many variables and doubles actually are the result of partial impact.

The evidence of these doubly variable double stars and their being associated with nebulæ is somewhat scattered, but much of it is due to the work of Mrs. Fleming, of Harvard; and Mr. Nangle, F.R.A.S., of New South Wales, has supplied a most remarkable example.

As investigations proceeded, the power of the theory of the third body to explain and even anticipate phenomena increased, until by studying varying depths of graze in the different orders of cosmic bodies and systems, not merely were nearly all the then known phenomena of the

heavens explained, but a great number of phenomena anticipated, which have since been discovered. The number has become so great that a well-known New Zealand mathematician, Mr. E. C. Gifford, M.A., Cambridge Wrangler, who won the Herschel Scholarship says: "It has had many of its predictions verified by subsequent discoveries, in a manner as striking even as the fulfilment of the predictions of Mendelief, based on the Periodic law. . . . In 1878 the facts on which the impact theory relied were few, though sufficiently striking, but now they are innumerable."

In studying depths of graze of colliding suns, it was found that when the graze was greater than a third of the whole mass, a kind of whirling coalescence must ensue. Such an event was thought to have given rise to our own Solar System. In this view the planets were pre-existing bodies revolving in any azimuths about one or both of the original colliding suns. These were swung into a plane by the whirl following upon the impact. The moons were pieces of cosmic dust captured by the planets when rarer than they are at present. In 1879 and 1880 the many agencies that gave present order to the Solar System were traced out. During the same years, by the study of the collisions of globular nebulæ, and by following the configuration produced by various depths of graze, all the nebulæ of exquisite form were seen to evolve.

By the interpenetration of vast cosmic systems such as the Magellanic Clouds, a coalescing group of bodies with a great central furnace, similar to that of the nebula of Andromeda, was seen to be developed. Then phenomena were traced on until the central furnace burnt itself out. Further on, the interpenetrating groups would evolve into a system of like configuration to that of our own Galactic System. So striking is the resemblance, that all the details of structure and distribution fit into their places with apparent perfection. Then agencies were traced, until a new aggregating power in addition to gravitation was found to exist in nature. There is a tendency for the light elements to be expelled from old systems by the high speed given to atoms. These tend to congregate in positions of high potential, where matter is sparse. This we called " the aggregating power of high potential." Agencies were found that elevated dissipating energy, and others that tended to disperse matter, until a complete mechanism disclosed itself; that rendered it possible that we exist in a cyclic scheme of creation, in which there is no evidence of a beginning or promise of an end, but a cosmic whole infinite and immortal.

Throughout the three decades during which we have worked at the theory of partial impact, deduction and observation have time after time alternately got in front of one another. Stellar

discoveries, that had at the time no deductions from theory to explain them, received explanations. This further study contained deductions passing beyond the observations; so that in some directions fact outstripped explanation, in other cases the facts had not been discovered that overtook the deductions. Especially has this oscillation of the progress of deducing theory and confirming fact been noticeable in connection with the fluctuations of period and intensity and other irregularities of variable stars.

Now there is only very minor want of coincidence at all. The peculiarities of the long period variables, of those of the Eta Aquilæ type, of S. S. Signi, and most others, are fully explained.

The fact that crowding of stars in star clusters would tend to collision was pointed out in very early days. Also that the nebulous matter so produced would act as a retarding agent in producing other collisions was studied. Arrhenius has independently worked out the same principle. All these peculiarities of variables in certain star clusters are now parts of established science.

It was anticipated that the light curve of variables produced by impact should generally rise more suddenly than it would fall, as is the case; but the amazing suddenness with which some rise is difficult to explain, and we know of no variables that correspond with the deductions associated with the penetration through a nebulous

sun of great mass and volume by a small dense star, or a small dead sun. So the race of theory outstepping fact and fact outstripping theory has gone on, and doubtless must do so for many more years.

There is an urgent need for a society for the study of questions of Cosmogony, or rather we want a Cosmophysic Club, where those interested in these deeply important scientific and philosophical questions would be able to meet for illuminating talk. There the military student of projectiles will meet the civil and mechanical engineer; the expert spectroscopist meet the astrophysicist; the experimental investigator meet the careful astronomical observer, each expert bringing his especial study to weave fact and theory into the useful fabric of a durable system of cosmic evolution. Then, perchance, celestial birth, maturity, death and rejuvenescence may be as well understood as is the mode of organic evolution. We want a home of union, where the wondrous discoveries of each specialist shall have their places allotted in the great conception of the complex structure of the whole Creation.

CHAPTER II

THE COLLISIONS OF SUNS

THE novelty or otherwise of the ideas and statements in this book is of little consequence. The important thing is, are they true and useful? Do they contribute to Living Thought?

Apparently very little novelty can now be claimed for any idea. Some twenty-four centuries ago Democritus, the "Laughing Philosopher" of Greece, seems to have had a storm of insight, and such a series of illuminating flashes of genius came from his seething brain, as perhaps comes to a man but once in the whole history of a world. He made a number of tremendous guesses, all of which are now realised truths. These guesses were not wild speculations, but the reasoned scientific imaginations of a travelled mind, saturated with the learning of the then whole known world. He guessed that the Sun was not the small disk it appeared to be, but an immense body seen from an amazing distance; that the stars were suns, still further away; that the milky way was an innumerable assemblage of stars, at a still more stupendous distance; that all matter was made

up of atoms, and that the Cosmic whole was imperishable and immortal; an eternal cycle of birth, maturity, death, and rejuvenescence.

Those who have travelled to the antipodes and have seen the Southern Cross make its encircling journey around the South Pole of the heavens, have seen the vast Magellanic clouds, and have seen the Sun and the Moon rise in the direction of the right hand instead of the left, have also seen that the beautiful bow of milky light that spans the northern heavens is continuous around the earth. This great rough ring or double spiral of luminous cloud, astronomers tell us, confirming the ideas of the ancients, consists of hundreds of millions of "fixed stars," each star a blazing, seething sun, moving at an inconceivable velocity.

Astronomical measures and statistics are as true and certain as, to our finite human minds, their magnitudes are inconceivable. That light travels at a speed of about 186,000 miles a second, is a fact demonstrated to be true by many means. That it takes light scores of years to travel from the average distance of our neighbouring suns is a certainty. So again there is no doubt that the inconceivable energies concerned in cosmic collisions, which a few simple calculations will present to us, are facts. The numbers are as certain and indisputable as the measure of the pressure of steam and the mass of a steel girder are to the engineer. Yet so amazing are these

numbers, that men of science have refused to read books that dealt with temperatures which are certainly exceeded in stellar collisions.

When problems are very complex, it is well to attack them piecemeal; we will do so with those before us. The question of atomic weight is concerned in temperature, and temperature is a complex idea. So, to commence with, we will leave both temperature and difference of chemical elements out of the question, and assume the bodies colliding to be similar in all respects, and to consist of a single element, such as iron, which has an intermediate weight. Again, the study of dynamics is rendered unnecessarily difficult, even repulsive, by lack of sufficient immediate steps, and terms to express those steps. We want terms like velocity, temperature, and potential, into which mass does not enter. So the molar kinetic energy contained in a unit mass of the material we are dealing with, we shall call Kinetol; and the heat or molecular kinetic energy contained in a unit of matter we shall call Thermatol.

The full treatment of dynamics would require a number of other terms, in order that it might be effectively taught; but to teach dynamics is not our present work; so we will not define these required terms. In the term "energy" the quantity of mass enters, and in most of the problems before us we do not know the mass, nor do we want to know it. All we want to know is the escaping

power, that is, the kinetol. Kinetol is proportional to the square of velocity. Energy is $\frac{1}{2}mr^2$, kinetol is $\frac{1}{2}r^2$. *

If we express cosmic thermal energy in terms of temperature we are faced with endless difficulties. Temperature depends on capacity for heat in a unit mass of the body, and capacity for heat depends on chemical composition, and on endless varieties of physical conditions. The term "thermatol" avoids all these difficulties. It is simply the number of thermal units in a unit mass. Of course, it is generally easy to calculate the temperature if we know the thermatol and the other data.†

VELOCITIES—THEIR EQUIVALENT KINETOL AND THERMATOL

The mile-a-minute train, as it flashes past us, impresses us with its tearing speed. The speed of a modern projectile is over half a mile a second, that is more than thirty times as fast as the train. But its kinetol is as the square of its speed, so the tearing power of the shell is about a thousand

* I do not use Sir Isaac Newton's term "vis viva" because different great writers have assigned v^2, $\frac{1}{2}v^2$ and $\frac{1}{2}mv^2$ as the value of this term.

† In addition to the above difficulties with the term temperature we have to define the scale, whether it be Absolute, Centigrade, Fahrenheit or Réaumur. Thermatol is always on the Absolute scale, hence it needs no other definition.

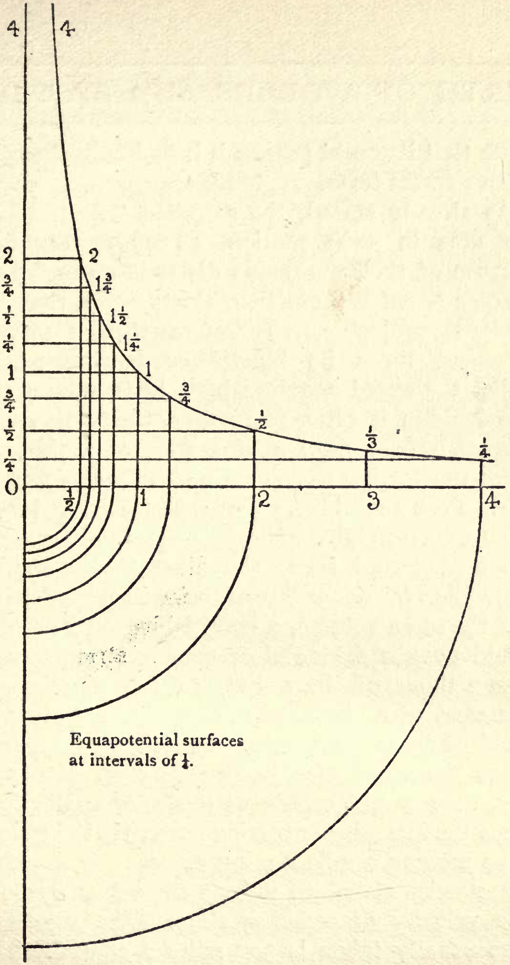

FIG. 6.—The Kinetic Curve. An Equilateral Hyperbola.
Curve of Potential of Kinetol or of Thermatol.

Horizontal lines represent distance from sun's centre; vertical lines represent potential, etc .

times that it would possess if it had only the speed of an express train.

As already stated, the so-called "fixed stars" are suns in swift motion. They appear fixed because of their enormous distance away. Their average speed is more than thirty times that of a modern projectile. Therefore they have one thousand times its kinetol or tearing power; whilst the speed acquired by a body falling on a massive sun is often more than thirty times the average proper motion of a star, or a thousand times the tearing force of the speed of an average star. Thus a shell has a thousand times the kinetol of an express train. The proper motion of a star has a thousand times the kinetol of a modern projectile. Were our Sun of thrice its present mass, and the same volume, a body falling on its surface would possess a kinetol or tearing strength more than a thousand times that of the average motion of a star, or a thousand million times that of the speed of an express train. That is, had a pair of trains the speed of a body falling on a massive star, they would collide with a thousand million times the intensity or tearing power that they have when moving a mile a minute.

Arrhenius gives 400 miles a second as a reasonable velocity of colliding stars. The velocity I have usually taken is 300 miles a second. This, as shown in Chapter I, gives us, when the onward velocity is converted by the collision into heat, a

thermatol of over twenty-seven millions, and were the specific heat of lead to remain constant, the temperature of two masses of lead colliding with that velocity would be $33 \times 27{,}000{,}000 = 891{,}000{,}000$. That is, nearly a thousand million degrees centigrade.

Such, then, are the energies of molar and molecular motions of unit mass, having a speed of 300 miles a second. These are the kinetols and thermatols we have to deal with, in case such an event should happen as the collision of a pair of suns.

The next question is, Does it happen? And again, if it does happen, are the suns most likely to meet directly in the straight line joining their centres of gravity, or obliquely in a hyperbolic orbit? We shall attempt to show that stars must occasionally collide, and that if the pair be similar to one another the collision must be of a partial or grazing character. We will also try to answer the important question whether if the graze be a slight one, partial impact ensues or not. That is to say, does the stupendous kinetol of the stars cause them to tear through and pass one another? Will the parts that had actually collided be sheared off, and be fused and welded into a third body? Will this cosmic spark be left between the passing torn suns, rotating, but approximately with no proper motion, the greater part of its colliding kinetol being converted into thermatol? In other words, will its onward

molar motion be largely converted into molecular motion, that is, into heat of an intensity of scores of millions of degrees thermatol

GRAZING IMPACT

All astronomers now admit the existence of an enormous number of dead suns, of perhaps more dead suns than the hundreds of millions of vivid stars. They admit that the stars are in two majestic processions, threading their stately way past one another in space; and so it is almost certain that sometimes they must graze. On these grounds, then, grazing collisions are now generally admitted by astronomers.

There is as much likelihood of suns, moving indiscriminately in space, colliding centre to centre, as of a blind rifleman hitting the centre of the bull's-eye. Occasionally, if he fires sufficient shots, he will hit the target. Occasionally, in the same way, stars will graze. Therefore the phenomena of grazing suns, not centre to centre collisions, form the question of supreme astronomical moment. Of course, small bodies will completely collide in an oblique direction upon large bodies; and it is dynamically important to know what will happen in the direct collision of two similar suns. But the general problem of colliding suns is that of grazing, the graze varying from a mere surface scrape of the outer atmosphere, to almost centre to

centre collisions; but before dealing with the commoner event, we must say a few words regarding the kinetics of a complete collision.

THE COMPLETE COLLISION OF SIMILAR GASEOUS STARS

Above a given temperature called the critical, all elements are probably gaseous. Stars are generally above that temperature, so the problem before us is the collision of free gaseous cosmic spheres. A common idea is that the heat energy produced by a stellar collision is so enormous, that it must make a nebula of the colliding pair; but this is not generally true, for the attraction of gravitation is likewise enormous, and tends to keep them dense. Clearly, in colliding stars the energy of proper motion has to be added to the energy acquired by mutual fall. The statement of the relative kinetol—trains, projectiles, and stars—already given, shows that in the example chosen proper motion only adds one-thousandth. It may be safely assumed that, on the average, proper motion does not contribute more than one-hundredth of the colliding kinetol. So although the complete collision of similar suns offers many intensely interesting special problems, it will be better not to fully debate them in the present volume. Long ago both Ritter and myself, by different modes of treatment and different modes

of statement of results, showed that in a complete collision of similar gaseous suns, the new sun would be only expanded to one-fourth the density; that is to say, the diameter of the new sun would be the sum of the two diameters of the two similar completely colliding gaseous suns. I also worked out the interesting result that all the colliding energy was exactly turned into potential energy of expansion, in this way leaving the new sun in possession of the same temperature as the old pair. Moreover, the condition was one of gaseous equilibrium and hence stable, and I further calculated that exactly double the energy of collision would suffice to disperse the body into an infinite nebula. Ritter's work is well known, and my original papers may be found where mentioned on page xix. As these problems are not vital to the development of the theory of Partial Impact, but only interesting illuminations, we will not pursue the results further, but proceed to show that the case of grazing collisions of suns, now admitted by nearly all astronomers as probable, must be a case of "Partial Impact." In this case two torn suns and an explosively hot third body are produced, and it is this third body which is the most important factor in cosmic evolution. It is so essential that the whole generalisation is sometimes called "The Theory of the Third Body."

CHAPTER III

PARTIAL IMPACT

FROM the foregoing it will be seen that there is but little, if any, difference of opinion amongst astronomers as to the assumption that dead suns are very numerous; that occasional collisions of suns are to be expected; and that the probability of an oblique impact is surpassingly greater than that of a collision centre to centre.

They would probably not contest Ritter's and my own coincident conclusions regarding the kinetics of complete collision, founded on the dynamical theory of gases, so that it is a most astounding thing, that the dynamical deduction that a third body must be formed has apparently not occurred to them. At least, it appears never to have been discussed in their writings. The Chief Librarian of the Warren Library of New South Wales, a gentleman who was at the same time President of the local branch of the British Astronomical Society, as well as many F.R.A.S.'s, after years of careful search, have failed to find it even mentioned in any recognised astronomical literature. This oversight is extraordinary be-

cause military, civil, electrical and mechanical engineers, as well as Professors of Engineering, consider that in a grazing collision of suns, the formation of a third body is a mathematical necessity; it is absolutely the only thinkable supposition when the question is made a dynamic proposition. This opinion is shared by Professor Morse, the astronomical expert of the Sydney University, whose report had been officially asked for. He gave, generally, a most favourable opinion, but was emphatic regarding the fact that a third body must be formed. Eminent Physicists, as well as great Engineers, are equally certain, and no argument has ever been urged to the contrary.

As will be seen, the third body is essential; it is a veritable Siegfried of the heavens; as our Teutonic Hero was twelve times as strong as any other man on earth, so the third bodies, during their short existence, may often possess, in proportion to their mass, twelve times the energy of any other cosmic body. This energy is so great that they must wholly or selectively blow themselves to atomic dust, and these wandering atoms possess so high a kinetol, as to escape not merely from the region where the impact occurred, they actually possess such enormous speed as to escape into distant space outside our very Galactic System itself. The question of the third body is thus seen to be momentous, and its formation

or non-formation must be answered one way or the other.

Let us assume that two similar gaseous stars or two similar dead suns are approaching in each other's path, and are about to graze. Let the orbits be such that one-tenth of each body will meet. Let us call the colliding velocity of fall of the two suns the "Critical Velocity of the pair," and the corresponding energy of unit mass the "Critical Kinetol of the pair." Of course, it is known that our Sun's "Critical Velocity" is the same, whether the orbit of the striking particle be parabolic or be direct. An equal number of gravitational equipotential surfaces are cut in both cases. So if we disregard distortion, the same velocity is acquired at the moment of contact, whether the fall be directly towards the centre or parabolic. Now we must differentiate between the Critical Velocity of a pair of suns and the Critical Velocity of a particle falling upon either of them. In the case of a particle the sun is assumed, for the purpose of comparison, to be at rest; in the case of impact of a pair of suns they share the distance of the fall between them, so that the kinetol is only one-half. Again, a particle falls upon the surface of the sun. Whilst with two suns in collision the centre of gravity of each is a radius away from the surface, the well-known law of potential is that it varies inversely as the distance, as shown in Fig. 6. The centres

of a pair of equal suns are twice the distance apart that a particle on the surface of either is from the centre of one; hence, again, the kinetol is one-half; so that the critical kinetol of a particle falling on to a sun is four times that of the critical kinetol of a pair of similar suns. And as the kinetol varies as the square of the velocity, the critical velocity of a pair of similar suns is one-half of the critical velocity of a particle, with regard to either of them. This is one reason why I use 300 miles a second as more probable as a mean velocity for stellar impact, than the 400 miles assumed by Arrhenius.

The question before us is, Have the colliding suns energy enough to shear one another? If the spheres are of gas, there is no cohesion, and there is practically no resistance to shearing. If they are rock-surfaced dead suns, the tidal deformation would probably have crushed the surface to powder, even if it had not fused it.

Before the impact the tide will have travelled through a quadrant of each spherical surface, and as the tidal bulge is at both extremities of a diameter, crest and sinus will have followed one another on every part of the circumference of each sphere.

Assume, however, the spheres to be each of solid steel. What about the work of shearing? Shearing is not a question of grinding up the whole mass, but of cutting a surface, and cohesion

has its superior limit in the latent heat of fusion. The available thermatol is 27,000,000; the thermatol of latent heat of fusion is seldom over 100; so clearly the suns are cut.

Look at it also as related to the problem of kinetol. As shown previously, a velocity of 300 miles a second has over three hundred million times the tearing power of the speed of an express train; just as clearly as before, we see that the stars cut one another. The parts that actually collide are torn from the passing sun. The two portions coalesce, fuse, volatilise and dissociate, and form an explosively hot third body, whilst the torn suns pass on their way, each with a fiery scar where it was cut. To emphasise the fact that the two suns are so little affected by the collision, the theory was called "Partial Impact."

How long has the encounter lasted? Let us assume that one-tenth of each has been struck off, and let us further assume the volume of each to be approximately similar to that of our own Sun. The long, groove-like cut is something under 1,000,000 miles long; the speed is 300 miles a second. The cut begins at and finishes near the centre of the line joining the centres of gravity of the two bodies. The surface has travelled half the distance of the cut, but each has to clear itself before the new cosmic spark is free. There are 3600 seconds in an hour; three hundred times

this is over a million. So when partial impact takes place in such an instance as we are supposing, the suns are clear of one another in an hour, assuming them to be of about the same density. Whether the pairs of similar suns be each smaller or larger, the impact takes the same time, because of the astronomical fact that the velocities acquired by mutual fall of bodies of equal density are proportional to the diameters. Let us take a concrete example, and assume two pairs of similar suns, one pair ten times the diameter of the other. The densities being the same, the masses are proportional to volume, which again is proportional to the cube of the diameter. The kinetol of the fall from infinity is directly as the mass, and inversely as the radius of the spheres. The mass is 1000, the radius is 10; $\frac{1000}{10}$ is the kinetol, which equals 100, and as the velocity varies as the square root of kinetol, it is 10, and as the diameter is 10, it takes the same time to cut a sphere of radius 10, if the density is the same, as to cut a sphere of unit radius.

So all partial impacts of bodies of the same density take about the same time; we may call it an hour. If the density be greater the time is less, if density be less the time is greater. So one may say in an hour a new world, which may be as great as our own Sun, and of surpassing brilliancy, has been born in space; a *Stella Nova* has appeared!

Before we trace the further development of

this amazing phenomenon, we will give some of the ideas of leading astronomers as to its importance and mystery. The late Simon Newcomb, in his "Sidelights on Astronomy," says: "A mystery which seems yet more impenetrable is associated with the so-called new stars, which blaze forth from time to time. These offer to our sight the most astounding phenomena ever presented to the physical philosopher. . . . A question of transcendent interest is the cause of these outbursts. It cannot be said that science has up to the present time been able to offer any suggestions not open to question."

Carl Snyder says: "Could they be closely regarded, the blazing-up of these *novæ* would doubtless be, in mere extent, the most impressive spectacle the realms of nature afford."

The late Miss Agnes Clerke says: "What they were, what they are, what they become, are all difficult questions to answer. But the crux of the whole problem concerns the manner of their vivification. A body previously inert is transformed, wellnigh instantaneously, into a radiant centre of immeasurable intensity. How is the change effected? What store of energy is laid under contribution to provide the astonishing spectacle? . . . Most of the alternative hypotheses have been discredited by the inexorable logic of facts."

Colonel Markwick, certainly one of the most

careful students of temporary and variable stars, says as to satisfactory theories of temporary stars, "Like snakes in Iceland, there are none."

Let us, by tracing the kinetics and kinematics of this wondrous Third Body, see if these writers' sayings can be justified by the event.

We will first compare the effect of a graze with that of a complete collision. We have already seen that whether the collision be direct or grazing, at impact the velocity of the blow is the same. Hence, if all the energy in each case be turned into heat, the molecular kinetol or thermatol is the same. And as the colliding pair are assumed to consist entirely of one element, the temperature produced by a partial impact and by a complete collision, of a similar pair of suns must be practically the same. We are assuming for purposes of illustration, as we did above, that in the graze only one-tenth of each body is cut off. So the new body is only one-tenth the mass it would have possessed had there been a complete collision. Hence, in this case of partial impact we have one-tenth of the mass brought to the same temperature as the whole mass would have attained in a complete collision.

The Critical Kinetol of a cosmic body is proportional to mass divided by radius. Let us assume the surface density from which the groove was cut was less than the mean density, and that this fact, added to the expansion due to the

original proper motion that has been converted by the collision into heat, has expanded the new third body to the same volume as that of one of the original bodies. Then the critical kinetol required to dissipate the new third body, or cosmic spark, will be proportional to the mass, that is, one-tenth of that required to dissipate the whole coalesced body, which would have been formed by complete collision, and would have consisted of the entire mass of the two suns. Therefore this excess of kinetol shows us that although a complete collision would not generally be an explosion, as shown by Ritter's and my own calculations, a small ratio partial impact is accompanied by an explosion. We have in the one case a small mass, the other case a large mass, both at the same temperature; the gravitational power of the small mass being many times less than in the large mass, there is not the attraction to hold it together.

Suppose you contest the accuracy of the figures as to kinetol given above. It is not important; you have simply to assume a still smaller graze. Let the graze be but small enough, the resulting spark must possess energy enough to blow itself to pieces. It must consequently, when first formed, be an intensely hot, unstable body, a huge bonfire, that will expand without any great reduction of temperature, and must consequently increase in brilliancy for some time. Presently,

as the expansion takes the atoms far enough away from each other, and from the point where the explosion occurred, the motion of the molecules will tend to parallelism, and there will be but few encounters between them. From henceforth the intensity of the light will lessen ; the luminous apparition of the new star will be but a shadow of its brilliant past, and will become invisible to the naked eye.

With the colliding suns of the same volume, the thermatol developed will be proportional to the mass. With suns of the same density, but of different volume, the thermatol being proportional to mass divided by radius, the thermatol will be as the radius squared. In either case the greater the mass of the suns the greater the thermatol produced by the collision. The smaller the ratio of the spark be to the whole, the more transitory the phenomenon.

The two most noted *Novæ* of late years were *Nova Aurigæ* and *Nova Persei.* The new star of Auriga indicated a velocity of about a third of that indicated by the new star of Perseus, this later new star being both the more brilliant and more transitory. Hence we conclude that the Auriga collision was a deep graze of small suns, and the Perseus collision was a slight graze of very massive suns, because massiveness gives high temperature, and smallness of ratio gives transitoriness.

PARTIAL IMPACT

The wondrous " Pilgrim " star of Tycho Brahé, which was both brilliant and lasting, was caused by a deep graze of very massive suns. The accounts of this star show it to have been an astounding phenomenon. All writers tell of the suddenness with which it appeared, and also of the rate at which it increased in splendour. It grew to be brighter than Jupiter, then brighter than Venus at Quadrature ; in fact it grew to be so brilliant as to be clearly seen at noonday. Its incandescence must have been at least a hundred thousand times the intensity of our own Sun. Yet this stupendous apparition appeared suddenly, grew to be more and more brilliant for a month or two, then, after about a year, it diminished to not one ten-thousandth part of its former splendour, and finally it disappeared from unarmed human observation. It would be worth while turning our most powerful photo-telescopic appliances to search the spot for indications of stellar wreckage.

What but a grazing collision of massive suns could supply fuel for such a conflagration ? How could such a mass cool so suddenly ? It could not possibly cool in the time. This theory suggests it did not cool at that rate ; it dissipated itself. It was too hot to hold together, so it was blown to atomic dust, and a vast proportion of its molecules were sent off travelling as independent wanderers in space. They would have gone on,

and will continue to go travelling, until they reach the empty parts of space; and there they will linger, and from the variety of their sources, the greatness of their number must be such that they must act as retarding traps to stay the errant members sent out from ageing cosmic systems, and so lay the foundation for the future formation of new cosmic systems of the first order, thus giving rejuvenescence to dying worlds and systems.

When we consider the vast dimensions of such a sun as Arcturus, even if Snyder's estimate of a million and a half times that of our Sun be an exaggeration, its dimensions must be, on the most moderate calculation, stupendous. When we think of such bodies colliding, we have fuel for a conflagration sufficiently vast to produce a temporary star of a brilliancy such as no history records, unless the collision should take place at an almost infinite distance from our system.

Although the wonder and beauty of new stars do not diminish, when we think of the phenomena that must ensue in the third body produced by the partial impact of giant suns, every trace of their insolvable mystery disappears. There is no more of an enigma about such phenomena than there is in the burning of a candle or the bursting of a bomb; they take their place as necessary events in the known order of creation.

Nor is the event merely destructive. When we

study the influence of difference of chemical elements, and the mode in which the weights of the atoms influence the results, we find that in studying such a collision we are confronted with an event of such building power, that "Constructive Impact" would not be an unsuitable title to give the whole series of phenomena.

CHAPTER IV

THE INFLUENCE OF CHEMICAL COMPOSITION

KINEMATICS OF COLLISION

SO far we have considered only the energy of the collision, that is, the Kinetics; but we must look at the Kinematics as well. We must also take into consideration the effect that differences of atomic weight and other elementary differences have on the problems. When we study the lack of balance of the momentum of the blow, we have to take into consideration the relative density of the concentric layers of each sun, and density depends on temperature, on pressure, and on chemical composition, and two of these agencies tend to make the surfaces less dense than the interior. Consequently, in each sun the rare surface of the one tends to cut deep down into the other, and so comes in contact with the denser material below. This difference in the quality of materials meeting produces a lack of balance of momentum. This lack of balance tends to allow the material to be dragged along in the direction in which the suns are flying. The opposite sides of the third body that is being formed, conse-

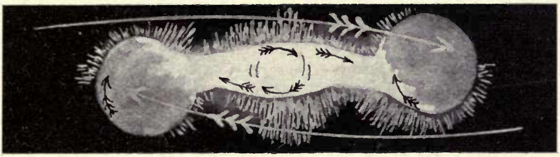

FIG. 7.—DIAGRAM SHOWING FORMATION OF SPINDLE AND ILLUSTRATING THE DIRECTION OF ROTATION IN THE THREE BODIES.

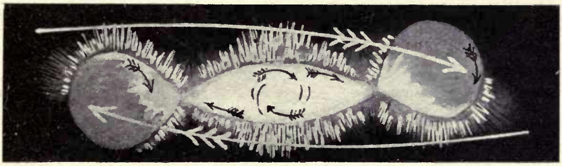

FIG. 8.—DIAGRAM SHOWING THE FORMATION OF THE HEATED MOUNTAINS AND SHOWING THAT IN ROTATING THE TORN SUN CARRIES THE MOUNTAIN IN ADVANCE OF THE VALLEY.

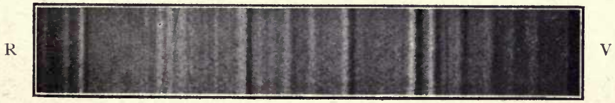

FIG. 11.—DIAGRAM SHOWING SHADED BLAZE BANDS.
A Spectrogram of Nova Aurigæ.

To face page 36

quently move onwards in opposite directions. This produces a "Couple," and the third body is set rotating. But as the cutting continues and the groove grows longer and longer, towards the end this lack of balance gets so extreme, and the material of the third body accumulates so much there, that as the three bodies leave one another, a great entanglement ensues, and vast white-hot masses of dense material are left at each of the parting ends of the third body, and also one on each of the escaping suns.

The accompanying diagram shows the condition immediately before and after parting. (See plate facing p. 36.)

The material at the parting-point must be subject to the attraction of each of the bodies, and to the onward momentum of the material itself. The material also in all four positions, that is, the two spindle ends and the mountainous masses on the torn suns, must chiefly be made up from the denser interior, and consist of elements such as iron, copper, and others of intermediate atomic weight.

The vast white-hot mountains on each of the escaping bodies will be tending to follow the escaping third body, and hence will cause each of the two torn suns to be set slowly rotating; but as both were probably rotating before they struck, the two rotations will struggle the one against the other, producing an internal rotation going in a different direction from the outer. It may be a

relatively long time before a steady rotation will be attained.

The molecular speed of the particles at the ends of the spindle and at the tops of the molten mountains will be such as to largely dissipate them. This material will be precipitated to some extent and form meteoric dust-clouds. These may become orbital about the torn suns. The white-hot mountains will sink, and the valleys will fill up, and the rhythmic oscillations may proceed for years. The influence of all these agencies will give extreme irregularities to the maximum of these variables. We will discuss these agencies more fully later on ; at present we will consider the properties of the rotating spindle-shaped third body, that is explosively hot, and occupies a position midway between the two retreating torn suns.

The centre of this body is made up of the two surfaces of the spheres, and chiefly of the lighter elements, the ends of the spindle being made up of heavier elements. The question of the effect of this variety of chemical composition will now be discussed.

ATOM-SORTING AND SPECTRA

Hitherto in studying the thermatol, or the heat developed by the collisions of suns, we have considered our spheres to be homogeneous. But suns are made up of a variety of elements, and we have now to ascertain the effect of variety of chemical

composition upon the many problems presented. It is clear, on grounds of equivalent energy, that if all the molar kinetic energy of bodies be converted into molecular kinetic energy, the molecular speed acquired will be the same as the molar velocity lost. So the 300 miles a second we have assumed as the molar velocity will be approximately the acquired molecular velocity. When the molecules of different elements move at the same speed, the temperature of the gas is proportional to the atomic weight. Lead will be two hundred and seven times as hot as hydrogen ; oxygen will be sixteen times as hot, and so on ; but it is clear that in a mixed mass, whose atoms are at different temperatures, and yet are surging and seething, the motion will tend to equalise the temperature ; especially so as the enormous pressure is producing expansion, and there is soon plenty of room ; which gives molecular movement free space to act and the various gases to mix.

Suppose in their excursions a heavy lead atom meets a light hydrogen atom, the great momentum of the lead will cause the light hydrogen to fly from it like a ball hit by a Demon batter. At each blow the light atom gains speed, until equality of temperature is acquired ; then, according to the law of Graham, the speeds are proportional to the square roots of the atomic weight, and as the kinetol is proportional to the square of velocity, the kinetol will be inversely as the atomic weight ;

that is, the kinetol of hydrogen will be two hundred and seven times that of lead. Now kinetol is escaping power, so hydrogen has four times the escaping power of helium, sixteen times that of oxygen, and so on. The following are the graphics of atomic kinetol and velocity:

At the first shock of the collision the tendency is for the temperatures of the elements to be different and proportional to the atomic weights. As the volume of the "cosmic spark" (the new third body) increases, room to mix increases, and the elements tend towards an equalised temperature. If ever this occurs, then the elementary atoms possess kinetols which are the inverse of the atomic weight, and the speeds are inversely as the square root of the atomic weights, as seen in the diagrams.

But the escaping power of hydrogen is very great, possibly a hundred times greater than the critical kinetol of the third body as a whole. So very soon it forms a vast ensphering shell of an enormous thickness. Helium will proceed to follow at half the speed, then other lighter elements will form shells, mixing with the hydrogen which will be continuously escaping outwards as its atoms free themselves. It must be remembered that at first hydrogen is at the centre of the third body. Presently our new third body (the cosmic spark, or *nova*), will consist of an intensely brilliant nucleus, surrounded by a series of ensphering

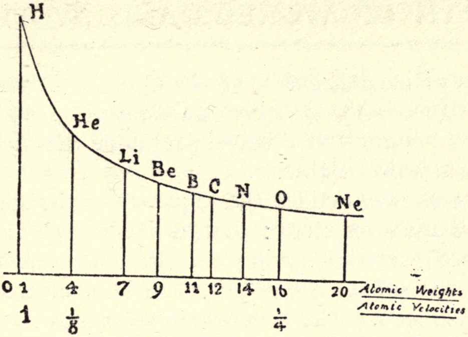

FIG. 9. Diagram of Atomic Velocity.

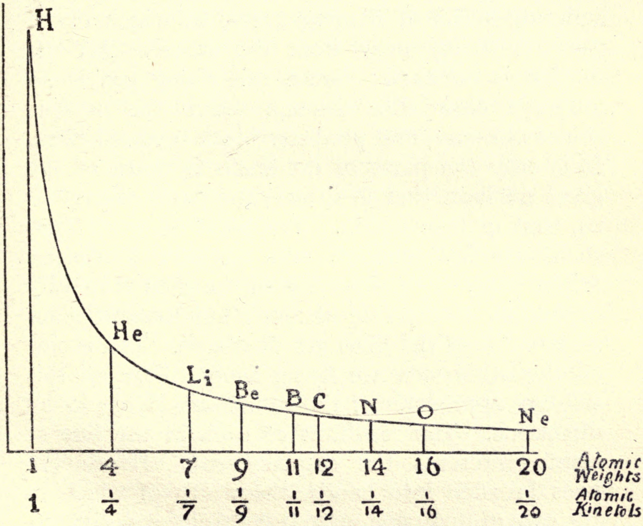

FIG. 10. Diagram of Atomic Kinetol.

shells of blazing gases, at the outside of which is hydrogen, and possibly nebulium. Then will follow helium and other elements in the order of their atomic weights.

Let us now deduce the sequence of the spectra. There are three steps: first, a blazing orb of compressed material, giving a continuous spectrum; then the sphere has acquired an atmosphere, first of hydrogen. The continuous spectrum is consequently cut up with dark lines of hydrogen. Then after a time those of helium come in; thirdly, we have a bright nucleus shining through distant ensphering shells of flaming gases, in which every atom is flying away from the centre. All the motion is outward; hence this flying gas is no longer a close skin through which the nucleus shines our way, and produces black reversed lines. It is only the parts of the shells in front of the great nucleus, that is to say, the parts nearest to us, that give reversion. The great masses of the shells are independent, and are now producing bright lines. Every portion of the shell is rapidly expanding at the rate of many hundreds of miles a second; so the lines are displaced. The atoms on the other side are flying away, those on this side are approaching; the atoms are flying in all directions. The resultant of each in the line of sight represents the displacement. Hence the lines broaden into bands, the width of which in the case of hydrogen may, it is readily conceivable,

represent displacement corresponding with velocities of a thousand miles a second in both directions. The helium band will tend to be half the width, and so on; but the width of the band will be modified by the power of the element to show itself, sodium being especially conspicuous in consequence of that power. Whilst, on the other hand, helium is generally very inconspicuous.

But the brilliant nucleus modifies the total effect. It eclipses the part of the shells immediately behind it; and the parts of the elementary shells in front tend to produce reversion of the isochromatic light of the nucleus, that corresponds in period with the characteristic lines. Thus if the cosmic spark be at rest in space, we get a brilliant broad band extending to an equal distance on either side of its normal position, and a broad shadow band extending beyond the bright band on the edge of the band towards the violet end of the spectrum.

The spectrum is also modified by a number of other agencies, especially by the varied motion produced in the third body by want of balance of momentum, due to the atmosphere of each sun tearing deeply into the heavy interior of the other sun, which is involved in the supposed collision. Diagram No. 1, fig. 5, shows the formation a spindle shape from this cause.

The ends of the spindle come from the deep parts of the groove that is cut in the near sun,

and have within them many such elements as iron and others of similar intermediate atomic weights.

The nucleus may not necessarily shine through this gas, and therefore there may be no reversion; nor will this gas be much robbed of energy by the light elements. So the lines of iron may not have shadow bands, and they may be much wider than the law of Graham would suggest. In a particular aspect of the revolving new star, very assertive bands such as sodium may appear cut in two by a black band.

Suppose we view the body equatorially; on one side the rotation is bringing material towards us, on the other side it is retreating from us, from which follows the broadening of the band. The portion in front of the nucleus is neither approaching nor retreating; it is moving across the line of sight, hence is not displaced, but it suffers reversion; so a black line in the normal position cuts the bright band in two. This explanation of a black line cutting a broad band in two applies to many stellar phenomena.

It is not now necessary to draw a diagram of such a spectrum, showing all but the suggested possible sodium line. The spectragram of *Nova Aurigæ,* published by Simon Newcomb in his "Side Lights on Astronomy," serves perfectly to illustrate the spectrum that would be produced were these physical deductions realised. The deductions were made a dozen years before the *Nova*

appeared and the spectrogram was photographed. In the identification of lines it must be remembered that width may be produced by the coalescence of two or more bands from different elements. The velocity of spherical expansion tends to loss of elementary definition in the same way as the use of a broad slit.

For diagram illustrating all the principles above described, see fig. 11, plate facing p. 36.

This diagram is not newly drawn; it is cut out of the late Professor Simon Newcomb's book, "Side Lights on Astronomy."

The cause of the Retention of the Displacement of the Black Lines, and of the Width of the Bright Bands, in the Spectrogram of Nova.

This retention of speed is the veritable crux in the study of the spectrograms of *Novæ*. How is it that an indicated velocity of 1000 miles a second shall show, as weeks pass on, no sign of decrease of speed? The fact, although it has astonished astrophysicists, was one of the first deductions made, from the properties of the light gases of the third body. It was shown that the amount of the kinetol of hydrogen, and other light gases required to escape entirely, was so small a ratio of the kinetols the atoms possessed, that in the case of hydrogen the diminished velocity would not be appreciable.

Nearly all the kinetol, so used up in the escape of a particle, is so used up at near distances; one-

half of the requisite kinetol is used up when the particle is a single radius away from the sun's surface.

According to our kinetic curve, the kinetol still required in any position to take a small body away to infinity varies inversely as its distance from the centre of the attracting body.

Let us look at the problem in the case of the hydrogen blaze bands. We have a nucleus and an enshering shell of hydrogen; the nucleus has been robbed of its energy by the hydrogen, and its heavy atoms are doing work by expansion, and the body is revolving. Hence as it possesses but a moderate store of kinetol, a quantity very small compared with that of the escaping gas hydrogen, its rate of expansion soon becomes a very small ratio of that of the ensphering shell of hydrogen.

When it is a relatively very small bright body, shining through a vast hollow gas globe, the amount of the absorbing surface of gas in front of the brilliant nucleus becomes so very small, that reversion ceases to be indicated, and the black lines die out. They do this without apparent diminution of velocity, because as the gas shell expands, the small part that is left still absorbing is that part which shows the maximum resultant speed in our direction on the earth. The series of spectrograms taken weekly by the Yerkes telescope show this retention very well.

Had the velocity of the hydrogen remained

quite constant the blaze bands would have increased in width on the spectrogram; because the reversion that made part of the band black would have ceased to act. The eclipsing effect of the nucleus, on the atoms indicating the highest velocity away from us, would also have been very much reduced. Hence if the velocity had been quite constant, the blaze bands would become wider before they disappeared than they had been earlier. They actually do appear so in some of the spectrograms which I have seen. But the hydrogen is all the time losing speed, and so the two agencies tend to balance one another, and produce an almost constant width of bands until they disappear.

This disappearance is due to the fact that, as the shells become larger, the distance increases, and parallelism of the motion of the molecules of the hydrogen becomes more perfect. Hence the encounters of the molecules lessen so much, that the luminosity becomes too small to record itself, and the hydrogen band disappears from the spectrogram, and does so before the nucleus quite ceases to give a continuous spectrum. This continuous spectrum in turn dies out, in consequence of the nucleus becoming a very rare cool meteoric swarm. The elements that give the lines to planetary nebulæ have formed shells, and henceforward they give their characteristic bands. It will appear, therefore, that there is entire apparent corre-

spondence between the complete sequence of the series of physical phenomena of the history of the third body and the series of spectrograms obtained of *Novæ.* A careful comparative investigation on the part of astrophysical spectroscopists is necessary to conclusively prove the elementary identity; this is urgently needed, but doubtless will be made when the physical properties deduced as belonging to the third body have been duly studied by astronomers.

It will be noticed that there is a distinct change in the cause of the expansion of the third body. At first it is caused almost entirely by pressure; partly by rotational, centrifugal force. As soon as atom-sorting begins, it is atomic kinetol, and not pressure, that acts. This change from pressure to kinetol is of extreme importance in the proper investigation of astrophysical problems, especially in Solar problems. There is another point to notice regarding the light curve of *Novæ:* pressure on a free gaseous mass will cause over-expansion; then there will be a fall back, and this again will produce increased pressure and increased light. There will consequently be fluctuations of light, as these rythmic pulsations of pressure and overflow alternate with one another. Gaseous escape will also first increase and afterwards lessen; hence the blaze bands will likewise be affected, and show corresponding pulsations of intensity. Sidgreave's photograph No. 192 R.A.S. slide shows this well.

It is thus seen, that when we take into consideration all the effects of the varying kinetols and velocities of the different elements, almost every characteristic of light-curve and of the series of spectra of *Novæ* receive clear and explicit explanations.

In the early days I had not expected that the ensphering shell would sufficiently absorb the isochromatic light of the nucleus to produce black bands ; but immediately I saw the black edges of the blaze bands in a spectrogram, I saw they had so inverted the light. Every other detail of the spectra was described in my first lectures on the characteristics of the third body formed in stellar collisions.

From the astronomer's descriptions of the spectrograms, I thought that the lines produced by the ignited gases of the torn suns could be seen, but in no spectrograms that I have examined can any such be detected. It is hardly to be expected that they should show ; I fancy, however, the torn suns might sometimes have an effect on the light-curve of a *Nova* in its intermediate stages.

I have always thought, and do so still, that almost all the luminosity of a *Nova* is from the third body. The rapidity of loss of energy, and the great proportion of it, that must belong to the coalesced mass, must make this new body the preponderating factor in deciding the luminosity of the whole phenomenon. I think it must be in

only a small number of cases that the pair of variables will be seen at all. Still, the position in space, where each of the large temporary stars has appeared, should be carefully examined to try to find a point of light of varying intensity, and it should also be examined to try to find the bright lines of a planetary nebula.

CHAPTER V

METEORIC SWARMS—STAR CLUSTERS—COMETS

WE have traced the varied distribution of the great store of energy of the third body. We have seen a small part of it used up in producing rotation, and in giving a spindle shape to the newly formed body, while two other small quantities of the energy of the impact convert the torn suns into variables. We have seen that the greater part of the kinetol of the onward motion of the coalesced portions has become heat. The lighter atoms have also robbed the heavy atoms of a large part of their molecular kinetol, and have used it to carry themselves away into distant space. A portion goes to make other molecules into the ensphering shells of a planetary nebula. We have now to trace what becomes of the heavy atoms after they have lost a large part of their energy.

The whole brilliant nucleus is revolving and expanding at an enormous rate, at first under the influence of pressure; after a time, however, this pressure gives rise to a free motion of molecules. None of the expansion of the light gases in forming

ensphering shells was due to pressure; it was entirely due to differences of atomic kinetol or velocity. Kinetol, we must remember, depends on velocity; it is, in fact, proportional to the square of the velocity.

The first expansion of the third body is mainly due to pressure, a pressure so enormous as to be equal to scores of millions of our atmospheres, but the expansion is so great, and so rapid, that the pressure soon lessens, and kinetol, that is, motion in free space, takes its place.

We will assume that the nucleus has lost much of its very light gases; a good deal of oxygen may still be left, however. Presently the temperature sinks to be low enough for oxygen, chlorine, fluorine, and other strong negatives, to combine with silicon, and with the positive metals; thus producing compound molecules. Oxides are singularly non-volatile, so they tend to aggregate into drops, whilst the chlorides remain volatile; and this chemical combustion tends to keep the nucleus heated.

The pressure of the heavy elements, and of the compounds included in the nucleus, has been gradually used up in doing work against gravitation, but as the nucleus is rotating the particles do not come to rest; each one assumes an orbit of its own. On reaching sufficient distance from its place of origin, it begins to return on a highly perturbed elliptical orbit. As the mass cools, the

particles aggregate into larger and larger combinations, until a vast revolving meteoric swarm results. This swarm is not kept apart by pressure, but by kinetol, and this kinetic energy being chiefly rotating in one direction, there is but little tendency for the nucleus to shrink.

This conversion of pressure into kinetol may not always extend to its centre. In the case of a deep grazing impact much pressure may be left for two reasons; the deeper the graze the greater the gravitating power of the third body, proportional to its kinetol. It is also the more likely that elements of great atomic weight will be present. It is true the very heavy elements will be at the ends of the spindle, as we have already seen, but the whole nucleus will tend to consist of the heavier elements; whilst atomic kinetol especially selects lighter atoms for its action.

One of the most curious facts concerning the third body is, that as it is being formed, the light atmospheres of the two suns come first into impact; hence they become its centre, and remain so as long as pressure alone is acting. As soon as the body becomes rare, atom-sorting commences, and gradually, as the light atoms steal energy from the heavy ones, and move swiftly, they escape outwards, threading their way between the heavy atoms, thus tending to leave the centre hollow. But pressure tends to fill it again, and in the case of deep grazes does so. This reversion of the place

of the atoms, and of the conversion of pressure into kinetol introduces many pretty problems of Kinetics, Kinematics, and Thermodynamics, that Gifford and I talked over, but they have been altogether too numerous for all of them to have passed beyond talk, and to have taken their places on paper. Doubtless when the whole subject has been fully developed, their solution will carry with it a surprising number of answers to the conundrums presented to us in celestial photography, especially Solar and spectrographic.

In the third body, then, the centre consists of the lighter atoms. In time these change places, and become its outside ensphering shells, and produce the blaze bands of varying widths, the width, as already shown, tending to lessen as the atomic weight of the atom increases. Some, however, of the broad bands may be due to the coalescence of the lines of elements. I do not certainly know if this is so, but it appears to me that the D. sodium lines and the adjacent helium line must coalesce; it may be worth while to ascertain if this is really the case.

Leaving this spectroscopic parenthesis, we come back to the nucleus that has now wholly or partially converted pressure into kinetol, and that now chiefly consists of an incipient meteoric swarm. Each separate elementary or compound molecule, each group of coalesced molecules, begin forming minute drops of mist. Each one is

in a separate orbit, and each is held in leash by the gravitation of the whole nucleus. Continually compounds are forming, continually molecules are coalescing, continually the minute drops grow by accretion, as their orbits bring the particles together. Continually, also, the non-combining elements, the atomic bachelor elements, helium, neon, nitrogen and argon wander out into the open space, to produce narrow blaze bands as the lessening luminosity of the swarm allows their light to assert itself. So, by accretion, the fire-cloud becomes a meteoric swarm. This swarm, according to mass, size and age, becomes the more minute swarms we call comets, and other more or less permanent meteoric swarms. Still larger swarms become star clusters. Deep graze becomes nebulous stars, and Wolf-Rayet stars, of which many perhaps were caused by such deep grazes as to be cases of what we have named whirling coalescence. But whirling coalescence belongs to another property of the third body, that it is our duty to discuss later on ; I refer to the attractive effect of the third body upon the two escaping torn suns. This attraction of the third body may wed the two into a double star.

STAR CLUSTERS

Before passing to the consideration of the attractive influence of the third body upon the torn suns, we must say a few words about star

clusters. The stars of clusters are probably small. When very old, clusters may coalesce into nebulous stars of a certain variety. The brilliancy of stars does not depend altogether on mass, but on many other circumstances as well, such as age, and more or less absorbent atmospheres. Hence the whole mass of a star cluster may be much less than that of a very massive star ; therefore, as far as mass is concerned, it may be that star clusters, as already suggested, may have been formed from the nucleus of the third body, which body was formed by partial impact of two very massive dead suns grazing somewhat deeply.

After selective molecular escape has ceased to act, and the nucleus is freed from its lighter gases, we have a rotating mass of cosmic dust. Oxygen seems to be an abundant element in nature, anyway, it is especially so in the Earth's crust. Almost every metallic oxide is much less volatile than the metal from which it was formed. Hence in a meteoric swarm, oxides will tend to become cloud formations, the drops of which will be likely to coalesce by contact, and large drops tend to rob small ones of volatilised matter, as in the ordinary water-clouds of the earth's atmosphere. This accretion into drops goes on continuously. The orbits of the particles are far removed from a single plane ; every particle tends to move in an orbit about the common centre of gravity, subject to the perturbing influence of adjacent particles.

The immense volume of the swarm has been almost wholly produced by pressure, while the retention of the volume is largely due to orbital motion. The greater the volume of a given swarm, the greater the potential energy compared with the orbital kinetic energy, just as the outer planets are retained in their orbits by their slow motion, and yet their potential energy is enormous. This is a remarkable and noteworthy characteristic of the dynamics of gravitation.

Whilst the rotation of the third body tended to bring it into a plane, the pressure acting on the mass, being practically uniform in all directions, tended to make it spherical, and this departure from a plane has also been aided by axial extrusion. So we have a roughly spherical mass, the particles of which are all tending to revolve one way, the sphere being broken by the two tendencies, the one tendency being to a spindle form in a line in the plane of rotation, and the other being axial extrusion, this latter tendency being at right angles to the plane of rotation. Both of these agencies are aiding to destroy the tendency towards a flat, or bun-shaped swarm. As there is then a chance that each meteor will pass the medial plane of rotation, impacts would be very frequent, at first tending to coalescence. When the particles had grown very large the members of the swarm will be becoming star-like, partial impacts would begin to produce nebulous

matter, that would act as a retarding trap producing further collisions, as described in the chapter on variable stars.

TEMPORARY STARS IN CLUSTERS

It has been shown that, generally speaking, in solar collisions the augmented energy of the fall due to proper motion is small; hence the orbit is but slightly hyperbolic. But the orbital motion of the particles of a star cluster must be an important ratio of the velocity of impact; hence temporary stars in clusters should, as a rule, be evanescent. But such a *Nova* might easily become for a time as bright as the whole cluster. There is another characteristic which might show itself. Atom-sorting has robbed such a swarm of hydrogen, and as the hydrogen of space would not have much chance to be collected, because of the high temperature and small mass of its constituents, hydrogen should, as a rule, be in a far less ratio to the whole than in the case of a body formed by whirling coalescence. Hence the blaze bands, so characteristic of temporary stars, should generally be feeble, or even absent from the spectra of cluster *Novæ*.

Clusters should be watched for evanescent bright specks, and, if possible, a spectrogram should be taken at once and successively, to see if such blaze bands are absent. Of course, variables

would be formed by the same kind of impacts that produce temporary stars. The clustering together of variables in certain star clusters, and in special parts of other star clusters, is a well-known peculiarity of star clusters, and will be further discussed in the chapter on Variable Stars.

COMETS

Whilst on one hand the partial impact of very massive suns may produce star clusters, on the other hand the impact of small planets may produce so small a swarm of particles as to form a comet. Comets, however, may also originate from the spindle ends of the third body. In my earlier papers I worked out agencies that seemed to suggest that, under special circumstances, the spindle form of the third body might become a double spiral, in which meteoric nuclei might form, and so solar systems be produced. This idea of the origin of our own Solar System, as mentioned elsewhere, I relinquished. I still, however, think that minor swarms may be produced in that manner, and may form the nuclei of comets; indeed, I think it probable that all comets are meteoric swarms, and that a single body of the mass of an ordinary errant comet, and in the same kind of orbit about the sun, would not be seen at all. I fancy, however, the impact of such single errant bodies near the surface of the sun may

produce the flash of light that has occasionally been seen, and that they may also, by plunging into the sun, be the detonators of an occasional sensational sun spot. But, taken generally, an errant single body visiting our system would not be perceived. The comet is seen because it is a swarm, and it is chiefly solar perturbations of the members of such a swarm that, by producing impacts, make the comet so brilliant and imposing a visitor. As a boy I saw Donati's Comet; I think it was stretching its scimitar-like form half across the heavens, a most impressive and magnificent sight I then thought it. And again recently, as an old man, I saw in New Zealand the immense straight tail of Halley's Comet send its beautiful glow more than half across the sky. It was so fascinating, that its wonder and beauty dragged me up in the small hours during the cold winter, morning after morning, to look at it; I walked long distances to get an uninterrupted view of its rising head. At three o'clock in the morning the light of its broad tail shot up like a white aurora; then, after a time, Venus rose, and detracted somewhat from its beauty; then, three or four hours afterwards, the glorious nucleus rose. It was too close to the sun to show to perfection; soon the light of the advancing dawn cut off a great length of the tail, and presently the rising sun overpowered the comet altogether. I made a sketch of it; and it was

surprising how its immensity dwarfed houses, trees, and indeed, all terrestrial objects. I hear that the season prevented its being well seen in England; but in New Zealand it was a glorious sight, far transcending anything I had imagined possible, according to any history I had read of its previous visits. The remembrance of the fascination of that sight has caused me to drift away from the story of the origin and character of comets in general.

Comets, then, are possibly all bee-like swarms of meteoric dust, kept together by mutual attraction, and prevented from coalescing by orbital motion. These motions the differential attraction of the sun disturbs by producing tidal distortion; this causes collisions, which again cause volatilization, and gaseous and cloudy meteoric dust. The friction also develops much electricity; the sun's heat in some comets must also produce volatilization. His radiant beams also light up the meteorites, and each particle shines as a full moon, when it is seen by us on the other side of the sun. The electricity acts directly and inductively. Forty years ago, an investigation which I made into the effect of heat upon electric discharge and conductivity, suggested to me that probably the sun was electrified. If so, then that solar electricity would cause a separation of the two kinds in the comet, the opposite kind being attracted, the similar kind repelled. This

attraction would cause the gas of the comet nearest to the sun to rise in potential, until the tension would become so high that disruptive discharge would occur, and a shell of gas would be expelled towards the sun. At the disruptive discharge the potential would sink to zero, and then again slowly increase, and another shell would separate, and these together would produce the concentric envelopes of the head of a comet on the side towards the sun. The comet is thus left with one kind of electricity only. This kind, under the repulsive action of the sun, possibly by induction, lights up the dust of space, and so the tail appears; it is probably a kind of electrical searchlight. It is curved, because the action takes time to travel; it is straighter when the induction is less self-retarding. The action is probably less self-retarding when the swarm is smaller. Some swarms must have subordinate centres; multiple swarms possibly give multiple tails. Perhaps the smaller the nucleus, the straighter the electric radiant beam. The inductive action meeting with previously existing electric conditions in space may cause other disturbances, and modify the forms of the tail.

Such, then, are some of the wild ideas that have deductively flashed upon my mind, when considering meteoric swarms. I know all too little of comets, and of the details of these amazing meteoric luminaries. These tentative ideas, al-

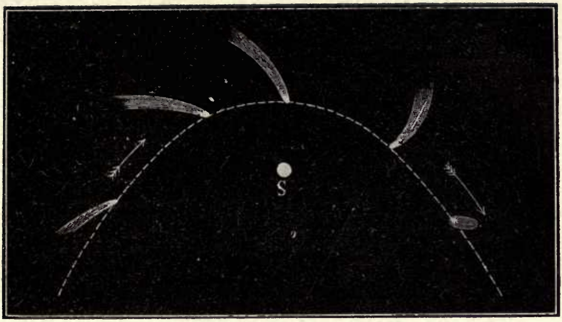

FIG. 12.—DIAGRAM OF COMET'S ORBIT.
The above diagram illustrates also the direction of the tail.

FIG. 16.—A CLEARLY CUT SPIRAL IN CANES VENATICI.

To face page 62

though a quarter of a century old, have not grown much, and are quite too immature to be of much use. They await investigation by the ripening and winnowing knowledge of those industrious workers to whom the characters of comets are as well known as those of their own children.

For diagram of Comet's Orbit, see fig. 12 facing p. 62.

CHAPTER VI

DOUBLE STARS AND WHIRLING COALESCENCE

AFTER the impact, the two torn suns are both of less mass than they were before; hence each when at a similar distance attracts the other less than before the collision occurred. Each one is also attracted by the new-born third body. What is the physical effect of this attraction? This is the problem we must now attack.

Let us assume that two equal suns have, each of them, lost one-sixth. The third body is two-sixths, that is, one-third the mass of either of the two original suns. The two suns are each five-sixths of their original mass.

The third body stands still in space, hence when the centre of gravity is at a similar distance, it acts twice as long on each of the two retreating torn suns as they do on one another. If we call the original attraction of each of the original suns 6, the mass of the third body is 2, and it acts twice as long on each sun as they do on one another. Hence the effective attraction of the third body is 4; that of each of the torn suns is 5. That is to say, on leaving the point where the collision

occurred, the total effective work of the attraction acting on each retreating torn sun is 9, whilst before the collision it was 6.

Clearly if neither of the two suns had possessed any original proper motion, the path of each would have been one of parabolic form; but we must assume that both did possess proper motion. Then the velocity of their respective proper motions must tell in the colliding speed, which will be greater than the critical velocity, and hence the orbit will be hyperbolic. Let us assume the critical velocity to be 300 miles a second, and the proper motion to have been 30 miles a second; that is, the ratio of the one to the other is as ten to one. The energy of unit mass, or kinetol, varies as the velocity squared; that is, the kinetol is as 100 to 1. So that proper motion of 30 miles is only equivalent in energy to 1 per cent of a critical velocity of 300 miles.

Now, according to our deductions, when the centres of gravity of the torn suns are at any similar distance to what they were before the graze occurred, the work due to motion is as 9 to 6; that is, the increase of the effective attraction at any given distance is an increase of 50 per cent, whilst on the other hand, the escaping kinetol was only 1 per cent too much, when only the old attraction acted. Clearly the kinetol will not carry the torn suns to an infinite distance. The slightly hyperbolic velocity has become elliptical;

the torn suns have been wedded into a pair of double stars revolving about the centre of gravity of the third body.

Supposing the original proper motion had been 300 miles a second, it would then have equalled the critical velocity, and would have doubled the colliding kinetol whilst the attraction would only have been one-half greater. The orbit would still be hyperbolic, and the torn suns would escape one another.

A proper motion anything near 300 miles a second is not usual, as far as our estimates of such go, hence the greater number of stellar impacts will probably result in double suns. The evidence is strong that this is really the case; and the probability is great, that quite a large proportion remain so close as to be spectroscopic binaries.

Were the third body wholly permanent, the orbit of the torn suns would be such an eccentric ellipse, that at each perihelion they would collide again. But the third body can never be wholly permanent; although, except in very superficial grazes, there will always be some cosmic dust left behind as a meteoric swarm, after atom-sorting has almost cleared the point in space where the collision occurred.

Before the torn suns reached aphelion distance, and commenced their return journey, the greater part of the expanding nebula of the third body would be outside their orbit, and the attraction

acting upon them would have greatly lessened. If the total attraction had become one-half, the orbit of the new double star would have become

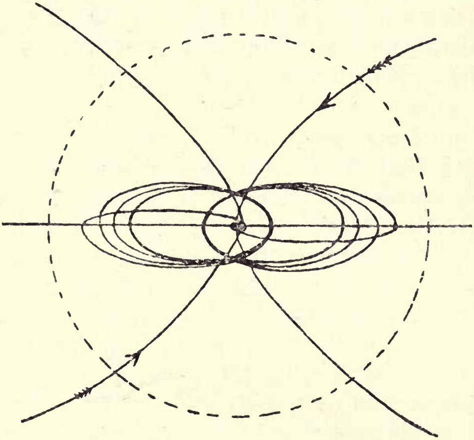

FIG. 13.—DIAGRAM SHOWING THE FORMATION OF THE ORBIT OF A DOUBLE STAR.

The dotted circle represents the nebula expanded beyond aphelion distance.

The two continued hyperbolas represent the path of the two stars had there been no collision. The collision occurring, the orbit becomes a long ellipse that becomes of less eccentricity because the nebula has expanded.

approximately circular. Generally the third body's loss, and the consequent reduction of attraction, would be great enough to make the

perihelion of the double stars much too distant for recurrent impact to take place.

There are other agencies still left to be accounted for, that will slightly lessen the eccentricity. These agencies were somewhat fully debated in a paper published in the "Transactions of the New Zealand Institute," date May 6th, 1880. The title of the paper is "Causes tending to alter the eccentricity of Planetary Orbits." There is one other agency that ought now to be mentioned, that under special circumstances may also be effective in lessening the eccentricity. The meteoric swarm will offer resistance at perihelion, which will lessen aphelion distance. The accompanying diagram shows the establishment of the orbit of a binary; it was used to illustrate a paper on double stars, read on August 5th, 1880, which is printed in "Transactions of the New Zealand Institute."

It is probable that most spectroscopic doubles, whether variable or not, have been associated by a partial impact. It is interesting to note that the number of the spectroscopic binaries, already observed and catalogued, that contain one dark sun, is very great. Of course, the number of detached double dark stars can never be known; but statistical probability suggests that they may be very numerous. Dark suns can only be detected by their effect on vivid stars; but as Sir Robert Ball points out, according to many lines of reasoning we must conclude that their number is enormous.

DOUBLE STARS AND COALESCENCE

Double stars may be formed by other methods besides impact. Two or more nuclei may be formed by bodies being entrapped in a nebula. If, as appears to be generally the case, such a nebula is rotating, these nuclei, on the contraction of the nebula to a sun, will probably form a multiple star.

Whenever three stars pass near to one another the relative velocities are permanently altered, as suggested in the capturing of comets by our major planets. The accompanying diagram, published originally in "The Romance of the Heavens," illustrates the formation of a double star by capture. It illustrates also how abnormal proper motion may be attained.

When once the stars have been wedded by impact, the union is generally an inseparable one. Some paroxysmal event, such as fusion in the great central furnace of a pair of coalescing cosmic systems, or forcible parting by the action of three bodies, or an impact, seems the only mode by which they may be parted. But there is another condition not so permanent. At their union they are torn suns, and therefore doubly variable; but such variability is only temporary. It may possibly last thousands of years, but the life of a double star may be hundreds of millions of years. Then again the two colliding stars will be of different mass; the lakes of fire consequently of different size and duration. Hence one wounded

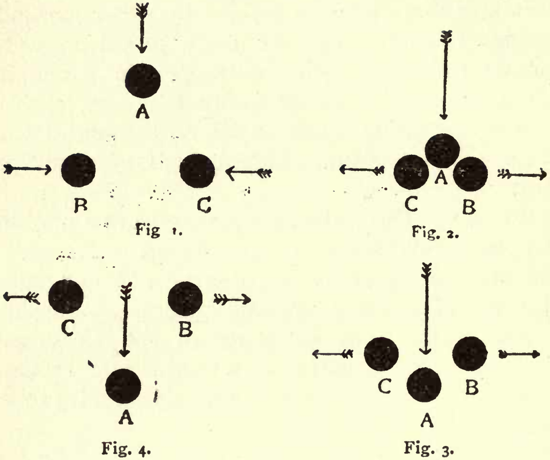

FIG. 14.—DIAGRAM ILLUSTRATING CHANGES OF VELOCITY THAT MAY OCCUR WHEN THREE STARS PASS NEAR ONE ANOTHER.

FIG. 1 represents two stars, B and C, about to pass each other. A, another star, is about to pass between the other two. The velocities, as represented by the arrows, are taken as about equal.

FIG. 2 represents C and B having passed each other. They have gained and lost velocity, whilst A is still approaching, so has gained and is still gaining velocity.

FIG. 3. The velocity of A is about the same as in fig. 2, the velocity, however, has been gained and lost, but B and C have still further lost velocity.

FIG. 4. A has a much higher velocity than in fig. 1, as B and C are further from it in leaving than in approaching. Whilst B and C have a lessened velocity, and hence may be orbitally connected into a double star, whilst the high velocity of A may carry it out of the cosmic system.

sun will heal before the other of the pair; both of the two stars will be associated with the nebulous meteoric swarm formed at impact; or they may even be entangled in it. All these peculiarities are common to double stars. They show conclusively that many double stars have certainly been wedded by means of partial impact; but these facts were best studied after some of the extraordinary characteristics of the many orders of variable stars have been studied. We shall attempt to trace their evolution in the next chapter.

When partial impacts are so deep as to cut away more than a third, the added attraction of the third body is so great that the torn suns may not escape at all. Such an event has been called whirling coalescence.

WHIRLING COALESCENCE

Suppose, as is generally the case, the kinetol of proper motion be a very small ratio of the colliding kinetol. Then suppose one-third be cut from each grazing sun. Assuming that at any given distance the original attraction of each sun was three units, then after impact each of the torn suns exercises two units of attraction. The middle body also exercises two units; but the centre of gravity of the middle body is at rest; so it acts twice as long. It has therefore an effective retarding effect of

four units; add to this the attraction of the torn sun, we have six units, whereas the original attracting effect was three units. The work of unit mass (the kinetol) to escape, is, at a similar distance, proportional to the effective attraction, which is now double of what it was. This would require double the critical kinetol to completely escape, so the available kinetol is one-half. One-half the critical kinetol is used up in moving a body one additional radius from the centre of a body, as may be seen by the kinetic curve (p. 17). Hence the torn suns do not part company with the third body; the two are drawn out into a kind of double spiral, which closes about the third body producing whirling coalescence. Atom-sorting and axial extrusion cause loss of matter, and the coalesced bun-shaped revolving mass may expand enormously, and become largely nebulous. I think it highly probable that Wolf-Rayet stars are examples of Whirling Coalescence.

There are many spectroscopic peculiarities of Wolf-Rayet stars, that are strongly suggestive of whirling coalescence; most of them have bright bands; some have broad hydrogen blaze bands, cut into two by a dark absorption band. It is clear that in a case of whirling coalescence the outer atmosphere will be revolving at a very high speed. If such a system be seen approximately edgewise, one side will be advancing towards the observer, and the other side retreating

from him, thus producing broad bands. The part immediately in front of the nucleus will be moving across the line of sight, and its lines will consequently be in normal position; but here the gas will absorb the isochromatic rays of the nucleus, and produce reversion. Hence this dark line cutting the broad blaze band in two.

One of the stars shows a distinct nebular gaseous disk surrounding a nucleus that gives a continuous spectrum. In this case the circular disc faces towards us. Nearly all these stars show bright bands of hydrogen, and other light gases; they are all found either in the Milky Way, or in streams of the Milky Way, or in the Magellanic Clouds; that is, they occur where stars are most abundant, and impacts consequently probable. Some of the characters of Wolf-Rayet stars are not easy to explain on this theory; but so many factors do agree, that it is probably only our ignorance or our defect of power to interpret the facts, that is the cause of our difficulties. Seldom has any problem been presented, but a lengthened study has ultimately solved it; anyway, the mass of favourable evidence is such as to render it highly probable that Wolf-Rayet stars are examples of grazes of stars so deep that the colliding bodies did not part company, but whirled around one another in the form of a bun-shaped star, surrounded by luminous gas. Many also of the characters of the bright line helium stars suggest stupendous and very rapidly

rotating suns, each with an enormous Chromosphere. They all seem to present some slight differences of character one from another. One in Cassiopeia seems to give a variable series of spectra. At present some of its gaseous bands of elements of small atomic weight are dark and broad; on this is a narrower bright band, and on this again a fine dark central line; such a complex band suggests an absolutely enormous revolving star. The broad black band is possibly produced deep down in the reversing layer, like the wings of the solar K. and H. Calcium bands. (Possibly in our Sun the Calcium is dissociated.) * The breadth may be due to dissociation, or to some other amazing molecular commotion. We have an example of even greater speed in the escape of helium from radium. The surface speed of rotation of the star may easily be hundreds of miles a second. Possibly, as suggested above of a Wolf-Rayet star, we see it to some extent edgeways, as we see Beta Lyræ, and other spectroscopic binaries. Hence one side is approaching, the other retreating; the atmosphere of blazing gas thus gives us the broadened blaze band that is superimposed on the still broader dark band; the thin black central streak is probably due to gaseous isochromatic absorption during the passage of this rotating gas before the nucleus across the

* For further explanation of this point, the reader is referred to Chapter IX.

line of sight. This explanation of the apparent double reversion for these two classes of stars may not be the true one; yet the agencies described certainly would produce a similar set of phenomena.

I take it, then, that many of the Wolf-Rayet stars and some of the bright line helium stars are vast revolving orbs, probably produced by impacts so deep as to result in coalescence. They appear to be of enormous volume; the Chromosphere being practically a nebula; they probably are also stars in which the whirl of the impact has given them a very rapid rotation.

To sum up, many bright-line stars appear to be very large, and rotate so fast as to have the character of a whirling gaseous nebula, surrounding a massive revolving sun. They differ intrinsically in character, and their spectra differ still more. This may be largely due to the varied angles at which the planes of rotation must be presented to our observation.

The bright-line variable stars are probably a special class, and are either torn suns or dead suns, into which a sun has plunged obliquely and produced a vast volcano. These stars are studied in the next chapter.

CHAPTER VII

VARIABLE OR WONDER STARS

MIRA CETI (the wonderful), whose vagaries have been studied incessantly since it was discovered by Fabricius in 1596, is the most notable amongst the many hundreds of such bodies now known to exist, whose number is added to monthly in the harvest of results given to astronomy by the modern armed telescope. This triune eye of science, built up of lens, prism and film, is the great revealer of celestial mysteries. No hawk-like vision of a Dawes or a Herschel can compare with the percipient power of this marvellous combination.

No one member of this triplet of wonders was known to Copernicus, or to Tycho Brahé. All are of modern growth, and have only been combined within the last two decades. The lens increases our light-gathering power a thousand-fold. The prism sorts the entangled light-telegram, and presents the cypher messages to us in orderly sequence. The photographic film takes in the light continuously, and for hour after hour goes on accumulating its records, until a luminous haze, so slight as to be scarcely visible

to the eye even in our most powerful telescopes, is not merely recorded, but significant details of structure are disclosed to the patient investigator, and not merely disclosed to his observation, but permanently recorded ; hence, for all time to come, they may be read. So that in case the eye of our minds cannot at present see the clue to the mystery, the message remains to be read in the light of future intelligence, enriched by all the wonderful discoveries of the living present and those of the hopeful future, which will probably be far greater.

These wonder stars, thus revealed to us, well deserve their name, and their variety is as great as their complexity. All are alike, in that the light we receive from them is not constant, but varies. Sometimes, as in the case of the Demon star Algol, with the regularity of a clock ; but the majority are irregular and erratic. Their vagaries sometimes seem to have an elusive kind of law, sometimes no law at all is observable. The quotation already given as to temporary stars applies equally to variable stars. " A wood of error " they have been named ; the mystery of variability of stars seems to astronomers inscrutable. By studying the dynamical facts connected with our demonstration, that a grazing impact must produce an explosively hot third body and two torn suns, much of their mystery disappears ; but enough is left unexplained to give a keen zest to further study. Whilst many suggestive deductions re-

main, down to the present unverified, to act as a spur to the further search of the heavens.

Already we have seen that the torn suns with their fiery scars must rotate, they are vast revolving searchlights, sending their amazing beams through the length and breadth of the heavens, and must shine as variable stars. Already we have hinted at some of the complexities of luminosity that must accompany those giant volcanoes, the blazing fiery scars. These volcanoes may be a million miles long, or much more, beginning with a slight valley where the plough of the other sun began to dip into it; the fiery valley along all its course growing wider and deeper, and finishing with a mountainous mass of blazing matter continuously altering its character. The gaseous uprush must be producing torrential rains of liquid, and perchance solid, metallic and rock matter. The pulsating fiery lake must for a time be alternately sinking and overfilling. The associated meteoric swarms, with their orbital motion, must be urging forward the mineral clouds in a most varying manner, according as the maximum of the swarm in their eccentricity coincides or not with the luminous part. The whole study suggests a complexity of varying luminosity, out of which at first one labours hopelessly to evolve any order. But some order must be there, and we will now endeavour to understand something of it; but first it may be as well, if in some small degree we

attempt to classify the varieties of these "wonder stars."

There are, first, the kind of which Mira may be taken as a type, variables in which the great volcanoes are carried around roughly about once a year. Then the next great branch of variables is that of the spectroscopic binaries, that is, stars that are known to be double, by the periodic shifting or doubling of their spectral lines. Many of such stars are, however, not now variable, as would be expected. Such stars, to be spectroscopically detected, require to be very massive and close to one another; so that their motion is swift; speed causes the displacement of their characteristic spectral lines to be greater and more easily noticeable.

These variable double stars are of many kinds. We have those of the Algol type, in which a bright star is eclipsed by a dark star, passing between it and us, the orbits of the pair being like rings seen edgewise. There are many such stars, and they have remarkably regular light-curves, that are quite symmetrical. Another variety consists of stars in which two bright stars eclipse one another; in such a case there are two minima in each revolution, as each sun alternately gets in front of and eclipses the other.

There is a tendency among astronomers to divide variables into those of long and of short periods; but they really pass gradually the one

into the other. Beta Lyræ is the typical short-period eclipsing double bright star. The two bodies are almost in contact. Clearly it may have originated in a case of partial impact, in which the constituents have just escaped whirling coalescence. Its vagaries are probably due partly to volcanic scars still remaining, and also to entangled orbital meteoric matter. Then there is also a class of variable stars, in which both the stars still distinctly possess the lake of fire, and are so close to one another that, as in the case of our own moon, tidal distortion has brought the time of their rotation into synchronism with that of their revolution. The best illustration of this type is Eta Aquilæ, although they are generally called Cepheids, after Delta Cephei, another member of this class.

These stars have proved a veritable enigma to astronomers; yet they are quite simply explained by means of the theory of partial impact; they are doubly variable double stars, that have been comparatively recently united.

Let us take the case of Eta Aquilæ. It has a period of 7 days 4 hours 14 seconds. It rises somewhat quickly to a maximum, sinks more slowly to its first minimum, then it rises to its second or smaller maximum, and sinks again. And all this it does in exactly the period of its revolution in its orbit, as indicated by the shifting of its spectral lines. Have we not here two

variable stars, each with the brightest end of its lake of fire foremost, as generally it must be, when of recent formation? This would produce the rapid rises and slower falls in the light curve. Tidal deceleration of motion has fixed each star so that they always present the same faces to each other; hence they both rotate and revolve in the same period. First one then the other of the volcanoes come into our sight; the volcanic lake in one star is brighter than that in the other star; thus are explained all the peculiarities of this type of star. Some of these Cepheids are irregular in maximum intensity, possibly indicating that the nebulous third body is entangled up in them, or from some other of the causes discussed further on.

Some variables have another peculiarity, they seem to consist of double stars, one or both of which are variable, and one has caught the meteoric swarm, left after collision by the third body; and this swarm, revolving about the star, swings it in its orbit as it revolves about the other large star, and in some instances the nebulosity can be detected. Whilst I was in Sydney last year a remarkable example of a doubly variable nebulous star with oscillating orbit was worked out by Mr. Nangle, F.R.A.S., President of the New South Wales Astronomical Society. This is a wonderful piece of evidence of the truth of this theory, and the case appears to be absolutely inexplicable on any other theory.

The star S. S. Signi has of late years attracted a great deal of attention, and a great number of persons have worked together to get a true light-curve for it. On making a very long, continuous drawing of this curve, such regularities and irregularities showed themselves as may receive an explanation by assuming a double star to be shining through a revolving meteoric cloud, thus giving us the minimum of the star, which is very nearly constant in intensity; the maximum is probably due to one of the constituents of the double star emerging from behind the meteoric cloud. For a time the star shows a series of maxima at comparatively regular intervals; that is, it emerges regularly from behind one side of the cloud; the cloud moves in its rotation or the apsides of the double star changes, and the star peeps out of the other side, hence its first interval is halved; then it comes out still further on the same side, giving us a longer maximum; afterwards in its rotation the cloud lets the star show through in another place. Thus we have a hint of the extraordinary mixture of order and disorder that characterises this puzzling star. But of all the variables, the long period ones appear to have attracted most attention, and these we will consider in detail.

VARIABLE OR WONDER STARS

OF THE VAGARIES OF LONG PERIOD VARIABLES

Never perhaps in the whole realm of nature has such a conflict of agencies been involved in a single phenomenon as in a grazing impact of suns. As we have seen, this complexity is not merely general, but each of the many bodies that evolve offers further individual complexities. Six or more of these absolutely different orders of bodies are produced by the one kind of event, a solar partial impact; and each one of these six orders is full of differences according to circumstances; yet the generic resemblances are even more striking than the differences.

In treating of long period variables, we are met both with these clear similarities and also these striking differences. Let us enumerate some of these characteristics, many of which we have already hinted at, as deductions from the theory we are demonstrating. The rise of light-curve should generally be quicker than the fall. They should often show nebulosity at minimum. For a time they should show rhythmic pulsations of rotation, and of sinking and overflow. Alterations of position and quantity on the surface of the material within the crater of the vast volcano, and alterations of the mountainous margins, especially the vast mass that precedes the valley. The obscuration caused by the clouds produced by the great commotion of rhythmic disturbances.

The alteration of the position of maximum uprush of the metallic vapours and gases of the great volcano. Obscuration due to orbital meteoric trains, and light effect due to the impact of eccentric trains of meteors upon the surface of the body itself. These are some of the factors that give an irregularity to the periods, and to the intensity of maximum and minimum. Many of these are not confined merely to the slowly revolving variables, but to quick orbital variables as well. Mira is a type of the slow class; I am inclined to believe that Mira is an exception to most of the variables, in that it may not have been formed by a partial impact of two suns, but rather by a somewhat tangential complete impact of a small sun with a huge sun, and the absorption of the smaller body into the greater, the small sun being perchance such a one as ours, and the large dead sun of something like ten times its diameter.

We have already mentioned that all solar impacts may be considered to take about the same time, owing to the velocity acquired by suns of the same density falling upon one another, being proportional to their diameter. The velocity of a body falling on to our own Sun is close upon 400 miles a second; if we take a large dead sun, Mira, to be ten times the diameter of our Sun, and of the same density, a body falling on to this would have a velocity of 4000 miles a second.

In using these data there is nothing in the

least degree improbable, so that the stupendous numbers that grow out of these astronomical dimensions, although inconceivable in their magnitude, may be taken as facts. The velocity I have used in the data already given is 300 miles a second; the velocity we deal with in Mira is 4000 miles a second, a ratio of 3 to 40, or about 1 to 13. Kinetol and thermatol are proportional to the velocity squared. The thermatol developed is therefore about one hundred and seventy times as great as that equivalent to 300 miles a second. We have already seen that this thermatol is over twenty-five thousand times that developed by dynamite. In the case of a sun falling on the body we have assumed Mira to be, the thermatol developed will be one hundred and seventy times this; that is to say, it is over four million times the thermatol developed by exploding dynamite.

The doctrine of probabilities shows that the small sun will strike the large one tangentially, and will cause the large one to revolve. The impact is over in about ten minutes; it produces an explosion whose power is as though a body had exploded some million of million times the mass of the earth, and consisting of dynamite. The explosion takes the line of least resistance, and blows out the material in its path, leaving an active volcano. We may ask, How long would such a volcano last? Will a thousand years be incredible? We simply cannot say. The problem

transcends our present knowledge; nor does our knowledge enable us to do more than see, that we need not refuse to admit any phenomena that we do not yet comprehend.

Already we have shown that there is a number of factors that must be fairly regular and consistent. As we continue to observe, with the questioning mind that is developed by such deductions, these definite factors will doubtless increase very much. One thing is certain: in future, hypothesis must guide research; it were folly for astronomers to proceed any longer making observations by mere haphazard.

I have looked into an advance copy of Professor See's monumental book, on the "Capture Theory"; it is full of suggestions. Unfortunately, this great and original thinker has in one thing dropped behind current astronomical thought, and does not accept solar impact; but his work is a most valuable contribution. Probably no one of us will agree with all his suggestions; but do not let us waste time and energy warring over his assumed deficiencies or errors. No gold mine but has its gangue; no grain grows without some chaff. Let us pick out the gold and grain, and use them for all they are worth. We have also already had Arrhenius's two books before us for some time; they are both rich in gold and grain, both are suggestive and inspiring. Shall we in our pioneering work refuse to take the paths already

blazed by these pioneers, because we see they have sometimes strayed? Personally, I believe Arrhenius to have given too great a value to the effect of the pressure of light. I also believe his diagram representing a grazing solar impact to be fundamentally wrong. It suggests that a solar crust is not burst by an energy equal to forty thousand times that of an equal mass of dynamite. I think the diagram is not merely radically wrong, but wrong, too, in every detail; but because I believe he has failed to see, as all other great men have failed to see, that a third body must be formed by the graze of suns, shall we neglect to use his other work? On the very same page with that erroneous diagram may be found most valuable data, which are over and over again used in this volume I am now writing, data and deductions missed by other eminent men. Working hypotheses are as important in high research, as a scaffolding is in order to erect a lofty building.

Let us now enumerate some of the facts deduced regarding these scarred suns. The fact that almost universally the most brilliant part of the volcano is forward. The fact that the blazing gases of the bonfire must generally produce bright lines. The fact that when once the struggles of the two rotations are over, the giant orbs must have a perfect period of rotation, however much such an apparent regularity may be interfered with by advance or retreat of the volcano's front, or by

other obscuring agencies. So these generic deductions must be mastered first; then others added bit by bit, as they and observation more and more completely coincide. The flutings that characterise so many of these stars are due to Titanium. I shall not now detail further the variability of the Mira class.

Before we pass on to the variables in star clusters, we will say a few words respecting the pairing of variables. This impact theory suggests that young variables must sometimes be in pairs. In very early days we plotted the variables given in Chambers' list, and found so many pairs, that statistically it was certain some law existed to connect them; no other law than impact and mutual tearing has ever occurred to any of us.

When I wrote the "Romance of the Heavens," in 1900, from Mr. J. E. Gore's list of suspected variable stars, I selected, from four hours of Right Ascension, such pairs of variables as seem distinctly to have been formed by the same collision. For positions see Table opposite.

The extraordinary coincidence that nine pairs of variable stars as close as these should occur within so small an area in proportion to the whole heavens—about one-thirtieth of the celestial vault—is obviously not the result of chance, and any sound theory of variable stars must account for such a fact.

VARIABLE OR WONDER STARS

R.A. h.	R.A. m.	Declination °	Declination ′	R.A. h.	R.A. m.	Declination °	Declination ′
3	38	23	59	6	33	6	9
3	39	23	34	6	35	6	27
4	14	19	31	6	43	13	33
4	14	19	14	6	47	13	20
5	1	8	48	7	8	22	28
5	3	8	54	7	9	22	43
5	28	4	55	7	26	3	32
5	29	4	56	7	27	3	27
6	31	18	33				
6	32	18	8				

OF VARIABLES IN STAR CLUSTERS

Where suns are thickly spread over the visible heavens, there we naturally expect to find the effect of collisions, and it is where stars are thick, as in the Milky Way, that there are variables in abundance. Stars are also thick in the Magellanic Clouds, and there again we find many variables. So many, that the average proportion, compared to the number of stars, that lie outside the boundary of the cloud, is so striking that, roughly speaking, variables seem to cease altogether.

Stars are thickest in star clusters, so in the systems we should expect many variables. But there is something also to be said against the probability of variables in clusters. Professor See

has but little belief in the collisions of suns; but he admits that suns in a nebula may collide, due to the retarding friction. If our theories of the origin of star clusters be true, there is but little light gas in star clusters, hence no retarding agency, so on that ground we should only expect occasional impacts. Then the stars of clusters are vivid, and it is not to be expected that vivid stars will retain a wound as long as dead suns; nor would small stars retain them as long as massive stars, consequently we must not always expect variables in well-ordered clusters.

But an impact turns even metals into gas; hence if a collision occurs, we have a nebulous trap, and some of the other suns of the cluster may pass into the nebula so produced, and be retarded, and then other stars may get entrapped, and this may go on as long as stars happen to be going that way. Presently the army of combatants grows less, and the fight is over.

Generally, stars are thickest at the centres of clusters, so there we shall expect most collisions. Then the chances are that the formation of variables will be regular, and extend to some extent symmetrically about the cluster. Suppose, however, a pair accidentally impinge towards one side, then it is not necessary that the nebula shall extend and cover the whole cluster; hence variables may be in a group unsymmetrically situated as regards the rest. Thus we may have great

irregularities in the variables of clusters; yet according to the number of stars, the stars of clusters should be proportionately more variable than other stars; as, in fact, they are.

There seems to be somewhat of a regularity of size of the stars in star clusters. If we have given a true idea of their origin, the law of probability suggests there should be considerable identity of mass and of density; hence a graze would set them spinning at something like the same speed. We have fully debated the reason why the light-curve should rise suddenly; it is that the motion of the mountain scraped by the other star, and left at the end of the long flaming valley, is the impelling motion that sets the star rotating; hence it comes into sight suddenly, and the light-curve leaps upward, and afterwards descends somewhat slowly.

Mr. Gifford and I have studied other varieties of variables, and other varieties of impact, that may produce variables differing from those given here, but I will not detail them now. I have here attempted to explain most of the examples of those variables that have been deduced and subsequently found to exist and those observed and the explanation afterwards found. The others are of interest to specialists, and will be worth while being treated in their proper place.

CHAPTER VIII

THE SOLAR SYSTEM

BEFORE we attack the problem of the birth of the Solar System, let us take a glance at its character and configuration. The sun with his satellites is one of a hundred million celestial kingdoms called stars. This group of vivid suns, together with dead suns, nebulæ, and other bodies and systems, make up the Universe in which we live. The earth is a colony held in leash by solar attraction. The Sun is over a million times the size of our residence, the Earth, and its mass is over three hundred thousand times the mass of the Earth. This particle of cosmic dust, our globe, is some 8000 miles through ; it seemed to me to be a big particle of dust, when recently I travelled half-way round it. The powerful engines throbbed and pulled for over six weeks to bring us here ; yet we travelled night and day, at a pace some four times as fast as one would ordinarily walk at. Still, compared with the whole galaxy, of which we are a part, this planet, the Earth, this immense globe, is a particle of cosmic dust.

The sun rules eight planets : four large, distant, and rare planets, and four small, near, and dense planets. The Earth is one of the smaller ones.

Besides these eight planets countless smaller particles of dust revolve around the sun. The relative distances of the various planets have generally a rough kind of order; this rough order follows what is known as Bode's Law. This law suggested that a planet was missing; where the missing planet should be, in the first year of the nineteenth century a minute body was found. Since then, hundreds of such small particles have been found, and it has been imagined that these particles are pieces of an exploded planet. Some astronomers have urged reasons against this idea of an explosion, but their reasons overlooked other agencies; and it is quite possible that a planet actually was blown to pieces. It is very easy for nature to blow a planet to dust. Revolving about most of the planets are small bodies called moons. It is probable that countless meteors also are revolving about the sun, which when lit up with the sun's radiance constitute what is called the Zodiacal Light. On a dark, clear night, exactly opposite to the position of the sun, we can sometimes discern a faint glow in the sky called the Gegenschein. This is probably cosmic dust; each particle has the sun shining full on it; so it is lit up, like myriads of small full moons. The meteoric particles are so small that we cannot see them separately, but they are probably so numerous as in their aggregate to cause this glow. The Zodiacal Light is probably the illumination of

meteors left behind in space, when the sun's general nebula contracted. They might have happened to possess revolving velocity, just enough to escape, during the general shrinkage.

There is still another wonderful set of particles revolving and forming a ring around the planet Saturn. Saturn's Rings form one of the most beautiful objects in the sky. Although other views are held about them, I am inclined to believe that these meteoric rings are parts of a moon blown to pieces. Certain dynamical laws seem to suggest that the component particles of an exploded moon would take exactly such a form.

There is a certain order in the distribution of all these bodies; they revolve about the sun nearly in one plane, called the Ecliptic; it is so called, because it is only when the Sun, Earth, and Moon are all in this plane, that eclipses of the sun and moon occur. Suppose we had a tub of water, and we floated an apple at the centre, and four peas towards the outside, and four grains of mustard seed spread out radially near the apple, and if the water were spun round we get a kind of rude resemblance to our system. The surface of the water is the plane of the ecliptic; the four mustard seeds are Mercury, Venus, the Earth, and Mars, revolving round on the inside; and the four peas revolving outside are Jupiter, Saturn, Uranus, and Neptune. Now, why do they all revolve in one plane, and all go one way?

There certainly must be some common cause; the Solar System is an orderly and definite system, not a haphazard collection of moving bodies.

What is the cause or origin of this order? It is a question full of interest to any intelligent thinker.

Two great answers have been given: one suggests that all originated from a common nebula, bun-shaped or spiral; the other, that the planets were entrapped by such a nebula.

Some thirty years ago, for a short time, I thought they originated from nuclei of condensation in a spiral nebula; I drew diagrams, and worked out many dynamical principles that made it likely. But I got too much order, so to speak; I became doubtful, for amid all the exquisite order of the Solar System there is likewise much irregularity, altogether too much irregularity for my theory, I thought. So most regretfully I gave up the spiral idea. We had worked out such a lot of pretty probabilities; we had seen that impact of two globular nebulæ must almost always produce a double spiral. Clearly one whirling arm of this double belonged to one nebula, the other arm to the other. Perhaps of the two nebulæ one was small and dense, and the other large and rare. So one might have given rise to the four small, dense, inner planets, and the other to the four rare, large, outer planets. We evolved all sorts of pretty possibilities, as can often so easily be

done with a wrong theory. That is one reason why I have never wept over the slow acceptance of the theory of the explosively hot third body. Personally, from the very first I was quite certain of that dynamical basic fact; but of some of the amazing crop of consequences, that grew out of that one dragon's tooth, I sometimes stood in abject mental fear. Wrong ideas, once planted in the human mind, are so mischievous, so slow to be eradicated, they so encumber the path of Progress. But now the snowball of the theory is rolling downhill, gathering as it goes; the enormous mass of newspaper notices proves the fact, that the theory is now here, and must be dealt with. It is of urgent importance that the scientific world should discuss the theory, thresh it well, and winnow out the chaff, before it becomes the food of the public mind.

So the double spiral theory was put on one side, and further search instituted. The idea of Capture came into my mind. Could the revolving nebula entrap the planets? Clearly so; but on the other hand, if the spiral nebula gave too much order, indiscriminate capture gave too little. Then, what possibly is the right explanation occurred to me, a suggestion that improves as more and more study is bestowed upon it. It is a kind of combination theory. The planets were captured by the revolving nebula; but they were independent bodies revolving in any azimuth, about one or

both of the original bodies whose impact produced the revolving solar nebula. Perhaps the four inner dense planets belonged to one original body, and the four outer rarer ones belonged to the other. Further study showed that all might have belonged to only one of the original bodies. We have had much talk over it, and opinions are still divided; the study of specialists may probably settle the point; anyway, there are clear dynamical agencies that tend to make one expect to find the order exactly as it is.

This, then, is the state of our idea of the theory of the origin of the Solar System, as far as we have got at present. We have not appreciably altered the idea for thirty years. The minor agencies tending to alter the eccentricities of the planetary orbits at this stage are non-essential, and are very technical. Those who wish to pursue the subject, will find the original paper on the agencies tending to alter the eccentricity of Planetary Orbits in the "Transactions of the New Zealand Institute," under date, May 6th, 1880.

The theory is, that the Solar System originated in a deep grazing impact of two suns largely gaseous. Revolving in any azimuth around one or else both of them were a vast number of independent bodies, some of which constituted the present planets. We have already indicated many modes, by which such bodies may be entrapped or developed.

The two gaseous suns plunge deeply through one another. The actually colliding part is at an excessive temperature and pressure. There is no relief for this compressed matter, save axially, so some of it is extruded. Selective escape comes into play as well, and a vast nebula forms. The non-colliding parts of each whirl round, and are drawn out into two vast tongues. They tend to take a double spiral form ; but possibly, in the case of dense bodies, this is soon almost obliviated. The speed of the collision is possibly over a hundred miles a second ; hence the first revolution of their tongues about the central furnace is quickly accomplished, and a rapidly revolving bun-shaped nebula results. Axial extrusion and atom-sorting lessen the attraction, and quickly the nebula expands, and goes on expanding until possibly it reaches a distance further from the centre than the orbit of Neptune.

The accompanying planets and other meteoric dust, which we have assumed as being associated with the original suns, possess the resultant of their original orbital velocity and the velocity impressed by the mutual attraction of the two original suns. Their original orbital velocity may take them anywhere ; the impressed velocity will be in the plane of the ecliptic ; the resultant of the two will take them all in one direction, namely, that of the general rotation of the nebula.

It is possible that the original orbits of the

planets were not as large at they are at present. Two agencies may have increased their distance from the centre; first, the lessened attraction due to the loss of matter by atom-sorting and by axial extrusions and by the outer expansion of the nebula passing outside their orbits; and secondly, by the increase of distance due to tidal action transforming rotary energy into potential energy of distance.

We assume that the associated bodies have been hurled into a direction that approximates, although very badly, with that of the equatorial plane. The orbits tend at first to be very elliptical; many agencies come into action to make them more circular, and many agencies tend to make them approximate towards the equatorial plane. Other agencies also tend to make the inner planets small and dense, and the outer ones large and less dense. Still other agencies tend to make the motion of the planets that are in the thick of the meteoric conflict, such as Jupiter, direct, and their axes perpendicular to the orbital plane.

We will try to understand some of these agencies. The centre of the mass tends to be the hottest part, and atom-sorting tends to cause that part to consist of the heavier elements. The inner planets consequently are likely to be at a higher temperature than the outer planets; hence the velocity of the light molecules tends to cause them to leave the planet. The material left behind will more

probably consist of elements of great atomic weight only. As the nebula shrinks, the planet picks up intermediate elements, and finally, as the solar nebula becomes so small as to shrink within the planet's orbit, the planet is possibly cool enough to allow the atmosphere to be picked up. This sorting action would not apply to the outer planets ; they would consequently remain rare.

Thus we see that, apart from original constitution, there is an atom-sorting tendency to make the near planets small and dense, and the outer ones large and less dense. This dynamical principle does not exclude the idea that the two sets originated from different bodies.

The influences of the impact of meteors and the accretion by means of them are very varied, and depend greatly on the position of the orbit in which they occur. An opposite impact at perihelion lessens aphelion distance, and increases the general speed of the orbit, and makes it more circular. It must be remembered that impact of bodies going in opposite directions is more likely than when both are moving the same way. Two bodies, each diagonally crossing the plane of the ecliptic and meeting, tend to a resultant motion in the same plane ; hence it is highly probable that the planets are now much nearer to revolving in one plane than they were at first.

The most important factor in rendering orbits

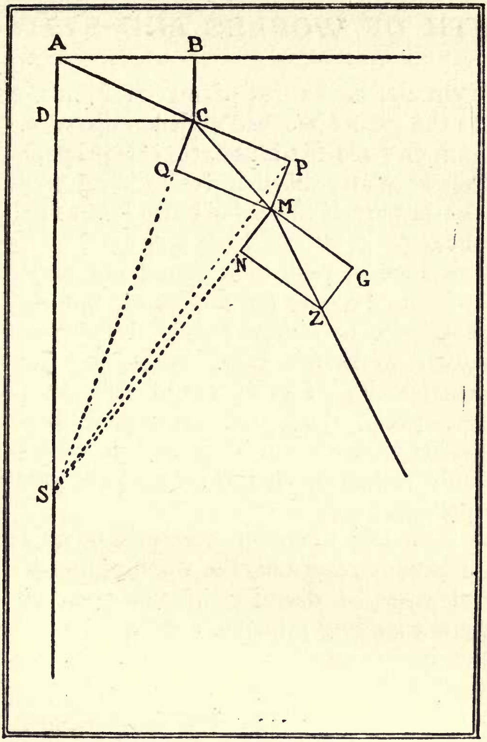

FIG 15.—DIAGRAM OF THE ORBIT OF A PLANET.

S represents the sun and A the earth. In equal times it should fall to D and be carried by its velocity to B ; the position it attains is C. Again, in equal times it would fall to Q and be carried by its onward motion to P ; it consequently reaches M. The same agencies take it to Z. Clearly in the next revolution when it reached A, if the sun now disappeared, there would be no fall, hence it would reach B. If the sun were lessened it is clear the earth would pass between B and C, and consequently at the opposite end of the major axis it would be further from the sun, and the orbit would be more circular.

more circular is the loss of matter from the sun, before the planet reached aphelion distance. The diagram on page 101 illustrates this principle.

Resistance at perihelion due to passage through the denser part of the nebula also lessens aphelion distance.

Resistance at perihelion would not only cause the orbit to become more circular, but it would cause apsides to revolve; this, I believe, to be the origin of Bode's Law. As apsides revolved the eccentricity of orbit would tend to clear a definite space; the planet would pick up most of the bodies that were in its path; the moons were probably picked up in this way at comparatively late periods.

There is still room for a surprising number of investigations regarding the wonderful order, and special cases of disorder, in the Solar System. The great guiding principle appears to be that all motion impressed at the time of impact, and after it, tended to regularity, and all motion existing before impact has left its impress in irregularities, such as retrograde motion, inclination of axes to the plane of ecliptic, want of coincidence in the planes of the orbits, and eccentricity. The light thrown upon all these matters by the researches of Professor Darwin, by Chamberlain and Moulton, by Lowell, by Arrhenius, and so greatly by Professor See, contributes to bring this most difficult and complex problem of the evolution of

the Solar System within the bounds of a speedy solution. There is no doubt but that the study of the exquisite order, and of the useful irregularities, of our Solar System, is not only most valuable for its own sake, but the solution of its many problems would throw a light on obscure questions in many departments of Astronomy.

CHAPTER IX

THE SUN

THE Sun is the nearest star to the earth; he is more than a million times as near as the average of the dozen other near stars. Consequently, being so much nearer, we can learn so much more of him than of the other stars; yet, because the stars differ much in character, a good knowledge of these bodies helps us to understand many points in the history of our Sun. Our triune eye, of lens, prism, and film, has recorded a vast mass of information regarding the complexities of the seething turmoil of his blazing surface; so large, in fact, that several considerable volumes might be written to tell the full tale of all that has been photographed, and otherwise learnt, of the war of the elements always going on in our ruling orb. Whilst, on the one hand, so much has been ascertained of the structure and movements of the solar surface, on the other hand surprisingly little is known of the agencies that cause these movements. It is here that the physics of the third body seems to be of extraordinary value, in offering hints of solutions; we cannot yet say in positively giving solutions; for that, further

analysis is still needed. The refining influence of fact has to purify the exuberant imagination's complex deductions. Observers and theorists should often meet for lengthy comparison of their notes as to these intricately interwoven phenomena. Now, however, is the time when suggestive hints and working hypotheses are urgently needed.

The theory of the third body offers many suggestions so clear, that most of them may be true solutions of solar problems.

What is the photosphere? It appears to be a cloud formation, yet cloud is liquid; and the Sun's surface is almost certainly above the critical temperature of every known element. If it is so, it is gaseous, and clouds in the usual sense do not form. A very beautiful theory ascribed it to carbon, but carbon sublimes at about 3500° C. The photosphere is very probably at 9000° C. What is the physical condition of the reversing layer? What supports the Chromosphere? Both of these atmospheres appear to be far too tenuous to suggest that outward pressure keeps them up. We shall attempt to show that all these questions may be answered, when we understand the clear line of demarcation, that divides gaseous pressure from orbital, convectional, and atomic kinetol. Possibly light pressure: ions, electrons, etc., help.

The photosphence is the limit of statical support, all above it is dynamically supported.

Then, again, we ask, What are the red protuberances, and the Sun spots? Why do the spots recur in a period of about eleven years? Why does each period begin with spots on both sides of the equator at a distance from it. Why do they then approach the equator, and after some thirteen years die out close to the equator? Why does the Sun at the equator revolve in fewer days than it does in latitudes far removed from the equator? Trade wind's action suggests the exact reverse. We shall attempt to show that these phenomena are effects due to meteoric bombardment by the cosmic dust of the Zodiacal Light and other meteors, acting as impulses reinforcing and directing the Sun's own tremendous energy.

We have already dealt in some detail with atom-sorting. To answer the above questions we must now deal with the dynamical theory of gases in slightly greater detail. The idea of a light hydrogen atomic ball being struck with the heavy bat gives the basic conception of the cause of the laws of the dynamical theory of gases. All these problems are complicated by the fact that elementary molecules may consist each of one or more, up to half a dozen, atoms. At present we shall assume all molecules to be monatomic; they probably are so in the Sun. The velocity of the several molecules of any given element at any given temperature is not constant. This difference gives rise to wonderful phenomena, and ex-

plains many difficult problems. But Graham's law ignores this difference, and for the present we will do the same.

The hydrogen atom is four times as light as the helium atom, sixteen times as light as oxygen, as is shown in the diagram of atomic velocity. When at the same temperature, the hydrogen atom moves twice as fast as helium, and four times as fast as oxygen. Their speeds vary inversely as the square root of their atomic weight; that is, the kinetol of hydrogen is four times that of helium and sixteen times that of oxygen. The kinetol multiplied by mass is equivalent to energy. That is to say, hydrogen has mass 1 and kinetol 16; that is, the energy is 16; helium has mass 4 and kinetol 4; the product is 16; oxygen has mass 16 kinetol 1; that is, 16. So at the same temperature the energy of all the molecules is the same, whether they be light or heavy. Hydrogen, the firefly of the elements, is as strong as lead, one of the atomic eagles. Looking at them as projectiles, at the same temperature each atomic small shot has as much energy as each atomic cannon-ball. This is the wonderful dynamical fact that gives the power of escape in atom-sorting.

When we increase temperature, we proportionally increase molecular kinetol. The atoms fly faster, but because kinetol is proportional to the square of the speed, four times the temperature

only doubles the speed; whilst it makes the kinetol four times as great. Hence the energy of a given mass of gas increases proportionally to the temperature; whilst the velocity of the molecules increases as the square root of the temperature.

Gaseous pressure is proportional to momentum, and momentum is mass multiplied by velocity; now the momentum acquired by a unit of mass depends on the time during which a given force acts on it; whilst the kinetol or energy of unit mass depends on the distance over which a force acts upon unit mass. Momentum $= F \times T$, and energy $= F \times D$. This time and distance view of momentum and energy is not generally used; yet it is vitally important in problems of cosmic dynamics. Pressure is dependent on momentum; at the same temperature the hydrogen atom has one-fourth the momentum of an oxygen atom, and hits four times as often; so it produces the same pressure. Hence the same number of molecules of any element, in equal volumes at the same temperature, produces the same pressure. If we compress any gas to one-half the volume, we heat the gas. If we allow the heat to escape, there are then twice as many molecules hitting an equal surface in the same time, and so the pressure is doubled. If we heat a gas to four times its temperature and keep its volume constant, the speed of the molecules is doubled; each molecule has double the momentum, but, because it moves

twice as fast, it hits twice as often, and each blow having twice the momentum, the pressure is four times as great; that is, it is directly proportional to the temperature. Thus easily are all the laws of the dynamical theory of gases explained; their comprehension is essential to the most elementary study of the Sun.

We must first contrast gaseous pressure and molecular kinetol. The pressure of a mixed gaseous mass is produced by all the elements mixed together, and each atom produces equal pressure. It is a general push, in which the atoms cannot run, because there is no room for them to do so. A gas must be very rare indeed to allow any considerable free path to its molecules. So we will assume that the Sun's photosphere is supported by pressure acting outward on its mixed elements; it is the extreme outer surface of such action. The whole photosphere must be tossed and riven and broken by amazing convection currents; these gaseous convections of flame may be hundreds of miles through. The many modifications of these flames are probably the willow leaves, or the rice grains, granules they are generically called. The flames would differ according to the depths they come from, their possibility of expansion, and many other things. The distance they come from also changes their elementary character, as will be explained further on. Mixed gas under great pressure gives a continuous spec-

trum; rare blazing gas gives the characteristic elementary bright lines; hence, as the convection flames burst through the general surface of the photosphere, and their momentum has carried them high towards the chromosphere, they would be rare enough, when seen in the eclipsed Sun, to give the bright lines of the spectra of the gaseous metals. When in front of the full Sun they would produce reversion.

To sum up, the photosphere is the general limit of mixed gaseous pressure. The reversing layer consists of the escaped gases that have been projected upwards by convection currents, and that are radiating and cooling, and will fall back again, still as a mixed convection current. The thickness of the reversing layer is some 500 miles; a velocity of projection of ten miles a second would suffice to carry the flames to that height. When the gas is very rare, the high kinetol of the molecules of the light elements allows of their escape, and they use their independent speed to run. Their motion is no longer produced by pressure, or by convection velocity; it is molecular velocity that keeps the gas up, each as an independent atom. Gas in this state of free motion almost certainly is what the chromosphere consists of; thus the photosphere is supported by pressure; the reversing layer by the speed of convection currents; and the chromosphere by selective molecular escape.

The Sun is giving off enormous radiation; the

whole coal-fields of the earth would only suffice to keep it up for a short time. This heat has largely to be brought from below, and vast gaseous convection streams must establish themselves, and must often originate at great depths.

But atom-sorting has some chance to act even in dense masses, and so the heavy elements probably predominate at the centre of the Sun ; while the lighter ones, those of less atomic weight, predominate as we get higher and higher. If there were no convection currents, these elements would, as the ages roll on, sort themselves fairly well. Thus, according to the greater depths from which the currents originated, we should have a preponderance of heavy elements. The elements will for this reason tend to be unevenly distributed over the Sun's surface. Photographs taken by the spectroheliograph will consequently differ, according to the elementary wave-rate chosen to photograph with. Thus calcium or any other element chosen will have its especial picture in the spectrum. It is risky for the imagination to take too daring flights, so we will now for the present leave these differential sorting agencies. We will now study for a little time the effect of the Zodiacal meteors, in case they should come into contact with the solar surface. The Zodiacal Light is probably a portion of the original storm of revolving meteors, that the Sun and planets have failed to absorb ; these meteorites must each move

in an independent orbit. The Gegenschein shows that this cloud of meteors extends beyond the earth's orbit. At the Sun's surface their mean velocity may be taken as over 300 miles a second; this, as molecular velocity, we have already seen, is equivalent to over 27,000,000 degrees of thermatol, and the thermatol of exploding dynamite we may take to average about a thousand degrees. Thus the forward push of a Zodiacal meteor may be considered to be over twenty-five thousand times that of an equal weight of dynamite. A one-pound meteor getting entangled in the solar atmosphere would be quickly volatilised, and would exercise a pressure on the surface of the equatorial regions of the Sun, and would urge the matter of those regions forward with a force equal to over ten tons of dynamite. As these impacts must be constantly happening, it is not surprising that the solar equator moves round in fewer days than the other parts of his surface. Of course, it is not the Sun's rotation that it is suggested is kept up by meteors; it is merely the accelerated velocity of the equatorial region. A meteor could give this differential velocity to many million times its mass; nor is it probable that this high velocity extends deep down into the mass of the Sun.

Next, what are the prominences? This tremendous gaseous projectile, the volatilised meteor, would expand and would exercise gaseous adhesion, and carry down into the photosphere vast

volumes of the chromospheric hydrogen. There would then be formed a violent volcano on the Sun's surface, and the hydrogen would be projected as vast tongues of fire; these tongues of flaming gas are probably the protuberances. The pressure of the solar surface would increase at an exceedingly rapid rate downward owing to its high gravitation.

Should we be wrong in assuming that a very big meteor would produce an incipient whirl, that would direct the solar currents into a vast cyclonic stream, and thus produce a Sun spot? The meteor being, as it were, the detonator, and the energy of solar currents the high explosive, the two together producing the cyclonic and other storms we call Sun spots.

But what of the Sun-spot period, and the wonderful sequence of the distribution of these spots? Some wild ideas on this subject have occurred to me, only to be taken as vague hints towards a solution. The dynamical difficulties that suggest themselves to me are appalling, but possibly they are surmountable. We will take the idea for what it may be worth. At one time an enormous meteoric swarm, a great comet, got deflected by the attraction of Jupiter and struck the Sun; it happened to have a direct motion. It was a partial impact, the centre being nearly cut out of the vast meteoric swarm. The theory of the third body suggests that such swarms must exist in

countless myriads, wandering as derelicts over the ocean of space. The two outside parts left were pulled by solar attraction into vast meteoric swarms, one on each side of the Sun, the two being V-shaped, with the two arms forward. The differential solar pull might extend the two swarms until the pair had become more than a complete circle of the entire orbit; but as each meteor would be in its own independent orbit, each train would tend to become spiral. Meteors might strike at perihelion, and the perihelion of the foremost and outer meteor would be further from the Sun than the point of the imperfect junction of the pair of streams. Of course, we must remember the V-shaped double swarm proceeds in space with its barbs forwards. I imagine the position of the spots in latitude must also be largely modified by the solar currents themselves. Here is a rough working hypothesis that may serve as a scaffolding to build a permanent theory on. I make the suggestion in the absence of any better one that I can think of. The spots being definite on the Sun's surface, this suggests that they are a solar phenomenon dependent on the Sun itself; while the long cycle suggests an external agent; so this suggestion is, as already mentioned, of double character, a kind of detonator and dynamite hypothesis.

There is some risk that in reading this suggestion, students may not agree, and may condemn

the theory of impact because of this somewhat immature suggestion. Please keep the two apart. The theory of partial impact and the third body, in its application to the phenomena of temporary, variable, and double stars, has so much evidence in its favour as to be, in the opinion of experts, a demonstrated deduction. This partial impact part of the theory should become codified science as soon as possible; the other parts, as has often been stated by experts, are possible, may even be probable suggestions, and must be taken only as such.

I have been asked by able astronomers as to my opinion of the corona. I imagine that, just as I have suggested concerning the tails of a comet, it is an electrical phenomenon due to solar disturbances; clearly the coincidence of form of its periodic modifications with the eleven-year period shows it to be due to Sun spots. It appears to be an induced electric action lighting up the dust of space, the site of each Sun-spot volcano being the electric generator that produces the electric induction, which gives the coronal rays; the general corona being an electric phenomenon due to the general friction of the Sun's surface. Whether this idea of the corona, and of comet's tails, be right or not, observation proves it to be quite certain that variations of terrestrial magnetic intensity follow with singular accuracy Sun-spot frequency. On one noteworthy occasion a brilliant point of light was seen on the disc of the Sun;

and this occurrence was synchronous with a most violent magnetic storm on the earth, and an unusual display of the aurora. That brilliant flash of light was almost certainly due to a collision between two bodies of considerable mass. If two such bodies met fair, the explosion of each unit mass of matter would develop thirty thousand times the energy of the same mass of exploding dynamite; so it would not require a very massive particle of dust to produce a fairly brilliant flash. I think it is extremely probable that the friction of collisions really must separate the two kinds of electricity, which also are further separated by the inductive action of the solar electricity. It is possible that, owing to the earth's rotation, all solar electrical phenomena produce by induction corresponding terrestrial magnetism. A kind of searchlight of magnetic influence seems to be emitted, not apparently by solar cyclones, but by the point on the Sun where the Sun spot originated; that is, if our theory of the Sun spots is right, by the friction developed by the volcano that has been produced by the impinging meteor or meteors.

It must be remembered that the Sun-spot period only introduces differential intensities of magnetism; the great bulk of magnetic action always remains with us practically constant. This bulk is probably produced by the solar convection friction, and by the continually recurring impacts of the dust of the Zodiacal Light.

As will be seen by the thoughtful reader, most of these ideas concerning solar phenomena are direct deductions from the properties worked out in the study of the agencies that are brought into action in the third body produced by grazing impacts of suns.

CHAPTER X

ON GASEOUS AND WHITE NEBULÆ

THESE two classes of nebulæ give respectively bright line and continuous spectra. They are, moreover, situated in contrasted positions on the celestial globe, the gaseous or bright line nebulæ being mostly situated in the Milky Way, the bisecting plane of which may be considered the ecliptic of the Galactic Universe. The white nebulæ, judging by their giving continuous spectra, are probably luminous dust storms. They are situated in two vast regions about the poles of this great circle. The cause of this contrast has already been suggested in the introductory chapter, and will be developed further in the next chapter.

The gaseous nebulæ in the Milky Way are of two orders ; the one consisting of vast aggregations of luminous gas without any definite form ; the other the planetary nebulæ discovered by Herschel. They are described by him as vast bubbles of gas ; many of them are still considered by astronomers to have this structure. We will study these hollow gas globes first.

ON GASEOUS AND WHITE NEBULÆ

PLANETARY NEBULÆ

The more that observation is devoted to these bodies, the more complex they are found to be. Generally they consist of a sphere-in-sphere structure; they often have a single or double star at the centre; or the centre may be occupied by a star of velvety structure showing a definite disc, probably a meteoric dust swarm. We will again study some more of the phenomena deduced as occurring in the third body produced by grazing suns.

MOLECULAR CHANGES OF THE THIRD BODY

We have seen that the atmospheres of the two grazing suns, being the first part to meet, will form the centre of the third body; whereas the heaviest elements, coming from deep down in the suns, are at the ends of the spindle, whilst the moderately heavy elements are at the outside of the third body. We will at present disregard the very complex motions set in action by unbalanced momentum, and devote ourselves to the study of the influences of temperature and pressure.

At first, and possibly for a day or so, pressure may be the only agent producing expansion. This expansion will proceed at a rate that will depend on the greatness of the colliding velocity, and the smallness of the ratio grazed off. The rate of expansion will be of the order of a million miles an

hour. Although the various elements will soon acquire approximately a common temperature, and the light ones a high velocity, many light molecules will, however, not quickly escape, as the crowd of molecules will be too dense. The reversal of the position of these light elements, from the centre to the outside, will proceed slowly and continuously. Possibly the whole of the light atoms will never find their way out. At first the concentric shells of gas will be continuous to the centre. We must remember that the problem is also complicated by the fact that, whilst the rate of the escape depends on atomic velocity, the power to escape depends on atomic kinetol. The whole mass of molecules tend to sort themselves into three orders.

The high velocity molecules, chiefly the elements of small atomic weight, that escaped outwards early, and other molecules whose kinetol is above the critical kinetol, would escape altogether, and largely go to form new cosmic systems.

The molecules, having approximately the critical kinetol, will tend to form hollow gas spheres of considerable permanency; these ensphering shells are doubtless the planetary nebulæ, which will usually have the light elements on the outside. Owing, however, to the fact that the light elements once occupied the interior, this rule is clearly not very rigid. The third set of molecules are those in which the kinetol is less than critical; these

molecules tend to be attracted back and form the central swarm or star. There is possibly a fourth kind of gas, gas in orbits taken out to distant space by rotation and atomic kinetol, and retained there by their individual revolution.

Often when the graze is deep, our studies have shown us, the double star consisting of the torn suns may also occupy the centre.

It must be remembered that there is no centripetal attraction within a hollow sphere, so that if a considerable ratio of the mass be in any shell, the tendency of the attraction is to give a definite outer surface, which is, in fact, a marked characteristic of planetary nebulæ.

The two ends of the spindle as they are dissipated, as well as axial extrusion, will each tend to give an irregular bilateral symmetry to such nebulæ; this also is a very striking characteristic of these bodies.

A spectrum of such a body would show a long, narrow, continuous strip of light produced by the central body. This should be cut across by bright lines; the lines of different elements would in general differ in length; the longest would be produced by the lightest element. Miss Clerke, in her "Problems of Astrophysics," Plate XXIII, Figs. 2 and 3, gives the spectra of Struvé's and Well's Planetary nebulæ; these two spectrograms show identically the characteristics already deduced. It is a most remarkable thing how

completely on all sides the physical details of the work on "Partial Impact," published thirty years ago, are being filled in by recent accidental discoveries.

The extensive gaseous nebulæ of the Milky Way are possibly portions of the great central fire of the Galactic Universe, that got entangled among the stars, and they may be masses of gas that accompanied the stars of the Milky Way on its outward whirl, after the chief part of the matter in the central furnace had been dispersed. I have not talked these nebulæ over with any experts; therefore I will not continue the subject at present.

WHITE NEBULÆ

The white nebulæ are most likely aggregations of the cosmic dust, sent to the poles of the Milky Way during the process of axial extrusion when the Galactic Universe was being formed. Nuclei would form in this vast field of dust by the entry of various bodies. The attraction would develop spheroidal nebulæ; the original proper motion of the entrapped star would often give the nebula an elongated form, or it might even be cometic. The entrapped body would give motion to the nebula; these motions would bring different globular nebulæ into grazing impact, of varying depths. Nebulæ of various volume and mass would also collide; all these variations of condition would

produce variations of structure. There is one striking general principle, that showed itself in our very first studies, and that is, that whatever the depths of the collision, from a superficial graze down to impact so deep as to produce whirling coalescence, each and every one tends to produce a two-armed spiral.

Slightly grazing white nebulæ during impact would appear to have a long spindle between them, because the first contact of the rare outside would develop heat, which may not be high enough to produce volatilisation or luminous gas. This would quickly settle to white-hot cloud. Hence such a spindle would appear to project to a long distance on either side of the two nebulæ. This spindle would soon show an incipient spiral, and in most cases this would develop into a double spiral nebula. There are many examples of this form in the heavens, one of the most striking is shown in the photograph. Fig. 16, facing p. 62.

Axial extrusion in the case of the Galactic Universe must have been accompanied with great heat; hence as the matter expanded, that formed the polar caps of white nebulæ, atom-sorting would largely have dissipated the lighter gases. So that, like meteoric swarms and star clusters, these nebulæ should be chiefly made up of rock substance and heavy metals. Of course such regions would not merely entangle errant bodies, but would also, when massive enough, entrap the

wandering hydrogen atoms, sent out from dispersing systems by atom-sorting.

There is always a tendency of cooling positive elementary metallic matter to combine with negative elements, and become converted into compound molecules. Oxygen forms very non-volatile oxides; in other words, the molecular attraction of oxides is remarkably high, so these compound molecules would tend to become solid or liquid particles, and form clouds. These particles would generally be kept from quickly coalescing by rotation; very infusible elements would, of course, act in the same way. Luminous clouds of all kinds, it should be remembered, give continuous spectra.

ELEVATION OF DIFFUSED ENERGY

Cosmic dust of this character, as well as all other cosmic dust, when cool would absorb the radiations that are streaming in such stupendous quantities from suns. Were the dust particles hot, they would not retain hydrogen. The heat of the dust would give a molecular velocity to hydrogen molecules moving with low velocity; this tends to take these molecules further from matter. There is always a tendency for matter, not in orbits, to use up velocity in doing work. The time occupied by a parabolic comet at high velocity is minute compared with the æons it occupies at a low velocity. Hence most of the

free molecules that are not revolving in orbits will have a low velocity, unless their kinetol is sufficient to take them from one cosmic system to another. Hence this mode of elevating energy, from diffused heat to gravitation potential, must be a very important factor in the economy of Nature.

ANOTHER AGGREGATING AGENCY IN ADDITION TO GRAVITATION

When a molecule travels from one cosmic system to another of equal attracting power, its slowest movement is attained at a point midway between the two. Where particles are moving indiscriminately, there will be, of course, a thicker distribution, wherever they move most slowly; hence this is an aggregating tendency which is the reverse of gravitation. The point in space where this is most effective is the point of highest potential, so that the aggregating agency has been named the "Aggregating power of the position of high potential." This agency, and the power of cosmic dust to pick up radiations and give this energy to light atoms, combined with selective molecular escape, which depends on the high kinetol of light atoms, taken together give us another aggregating agency in addition to gravitation. The cause of gravitation is, in modern science, still indefinite; this agency is apparently a mathematical *vera causa* and indisputable. This set of

agencies, which we may perhaps call levitation, together with gravitation, tend to aggregation; the one tends to collect the elements of small atomic weight in the empty regions of space; the other tends to collect all elements of great atomic weight and concentrate them where matter is already dense. Taken all together, they show agencies for the concentration and the diffusion of matter, and the elevation and degradation of energy. The whole series of agencies suggests that the theory of dissipation of energy is but a phase in an eternal cosmic rhythm. Consequently, the dismal doctrine of eternal death was founded on imperfect data, and is almost certainly misleading. This idea, that there is no rejuvenescence of energy, attributing imperfection to the order of creation, has led to an idea of endless minor imperfection in the cosmic scheme, until men have taken pain and disease, poverty and misery, to be inherent evils of life, instead of mere indications of wrong action. This idea has produced a pessimism so common and so prevalent, that men of high culture have seriously asked the question, "Is life worth living?" instead of accepting the encouragement of Browning's optimistic view of life, "God's in His heaven; all's right with the world!"

CHAPTER XI

REVIEW OF THE ARGUMENT

THE preceding chapters show us that in dealing with the impact of cosmic bodies and systems, we are treating a subject of extreme variety and complexity. It is demonstrated that the energies and momenta we are investigating are of so stupendous a character that the forces of cohesion, volatilisation, and chemical affinity become insignificant, when compared with the gravitational forces of the vast masses we deal with in cosmic calculations and hypotheses. On the Earth the tenacity of steel, the expansion of steam, and the power of dynamite appear giant forces and energies beside the pigmy strength of any animal. In comparison with cosmic collisions the most stupendous volcanic outburst, the most disastrous earthquake, sinks into insignificance. The mind refuses to completely realise the contrast, until years of study saturate it with the greatness of the thermodynamic intensities, that we are dealing with in cosmic space. The certainty that our vast earth is but a minute speck of cosmic dust, absolutely insignificant in the

ocean of space that lies within our own cognisance, to some extent introduces us to the idea of the vastness of cosmic energies.

The continued reference to combustion, to the surface tenacity of dead suns, and to the impact of planets with suns, in the study of *Novæ,* shows us that the scientific mind is not so penetrated by the importance of these immensities as is essential. Not even is it so in the case of men dealing with these very problems themselves. Without long study our minds refuse to realize that the blow which an ounce meteor gives in falling upon the solar surface must be something like the explosion of a ton of dynamite, and that a single meteor could give the abnormal surface velocity of the solar equator to fully a million times its mass. Yet such data must be living facts constantly retained in the minds of men who are dealing with celestial dynamics, and more especially celestial thermodynamics.

When the brain has learned this fundamental principle of the vast energies it is dealing with, it has also to get used to many other new thoughts. We have to strip off the idea of earthly weight, and think only of mass in free space, we have to clearly comprehend gaseous kinetol as contrasted with pressure, and the many other agencies already referred to. When the mind is thus freed from earthly entanglements and dimensions, the new orders of problems are found, as a rule,

to be far from difficult. We will now gather together some of these ideas.

The first fundamental fact is that slight grazing impact of suns must be partial. On dynamical grounds it is quite, indeed absolutely, certain that an explosively hot new body must be formed by the coalescence of the parts shorn from the colliding suns, and that these torn suns must pass each other in space. This fundamental idea of the formation of a third body appears to have been absolutely missed in the study of the stars. Anyway, as already stated, a number of careful Australasian readers, who have been on the look-out for years, have failed to find it even mentioned in standard astronomical literature.

It appears that the basic conception of this unstable third body is absolutely essential to every problem of celestial evolution. It is basic and fundamental in all problems of temporary, variable, and double stars, and of planetary nebulæ. It threads itself through the conceptions of the origin of most other nebulæ, and of the genesis of our Solar System. It is basic in the study of the interpenetration of vast cosmic systems, such as probably formed the Galactic Universe. In fact, those of us who have used the idea have found no cosmic problem in which it is not directly or indirectly involved. If this fundamental thought is left out of all old cosmogonies, and it is shown to be absolutely essential,

then it is clear, the whole of the theory of cosmic evolution must be rebuilt.

We will attempt to collect together some of the ideas we have been discussing, that are based upon the idea of this unstable third body. As the atmospheres of suns are the first to meet, these light gases become the centre of the new body. In an hour or so the third body is formed, and free from the colliding suns, which have passed on. The light gases at the centre are subject to millions of atmospheres of pressure. The small mass of the body and its enormous proportional energy allow it at first to expand at a great speed, without much loss of temperature. In a few days it has become an extremely rare gaseous nebula. The hydrogen has then something like a hundred times the thermatol of the mean of the elements. It has ten times their mean velocity, hence it tends to reverse its position ; it escapes gradually from the inside to the outside. Hydrogen and helium then form ensphering shells, expanding at a speed of hundreds of miles a second. The heavy elements have been robbed of much of their energy ; they perform work against gravitation, and therefore grow cool. Pressure ceases in the nucleus. Pulsations of expansion and contraction occur at the surface, and the dying light-curve oscillates. The volume of the nucleus and ensphering shell is no longer produced or retained by pressure, but by the orbital motion of its particles, and by mole-

cular kinetol. This noticeable physical change explains also the chromosphere of our Sun; the photosphere being the limit of ordinary gaseous pressure; the reversing layer being supported by convectional velocity; above the reversing layer all gas is supported by atomic kinetol.

This reversion of the position of hydrogen in the third body, conjoined with its spindle form having metallic ends, explains to a great extent every phase in the series of spectrograms of *Novæ*. Much, however, yet requires to be studied of the complex details. The outer ensphering shells of gases, thus expelled from the new star, have a great kinetol, and this is sufficient to take the atoms from the Galactic Universe into the empty parts of space. They are retarded there by the aggregating power of the position of high potential. These agencies show us there is a second aggregating agent in nature, that tends to the concentration of light atoms, as gravitation tends to concentration of heavy atoms. After this gas is all gone, all molecules having about the critical velocity, or having orbital motion, tend to form the ensphering shells of planetary nebulæ, and a central meteoric swarm. This meteoric swarm, if small, may be the nucleus of a comet; if it be stupendous, then after long ages it may become a star cluster.

The central body leaves temporary mountains of heated matter at the ends of the long grooves, cut

in the two torn suns by the tearing away of material that forms the third body. The mountains are near the ends of the spindle-shaped third body, and are left behind because of unbalanced momentum.

This mass causes the torn suns to rotate, mountains forward, and this rotation produces the quick rise of the light-curve, The gravitation of the torn suns tends to make each spherical ; it tends to pull down the mountain, and to fill up the valley, and it does both of these things. It overdoes them, and then rhythmic oscillations may give extreme irregularity to the light-curve of the variable star.

A great portion of the ends of the explosive third body may become meteoric cosmic dust. This nebulous matter may associate itself with the torn suns. When the star shines away from us, this dust is lit up on our side ; each particle being then to us in the position of the full moon. This dust may form orbital clouds revolving about the torn suns, giving further irregularity to its light-curve. A pair of variables is born at once ; many variables are still in pairs.

The third body exercises a great retarding power tending to wed the two torn suns into a double star. Double stars so wedded should at first be doubly variable ; there are, in fact, many such doubly variable double stars. Variables of the *Eta Aquilæ* type are almost certainly close

doubly variable double stars. One or the other of the torn suns of doubles should long retain its variability; there are scores that do so. Doubles should sometimes be the centre of planetary nebulæ; many are so. Doubles should be nebulous. Herschel says, "The association of double stars and nebulæ is remarkable."

There is nothing to prevent a dead sun colliding with a vivid star, there are innumerable such combinations. The dead sun may be the more massive of the pair; many are actually so. Thus simply is explained what Miss Agnes Clerke calls "an Astronomical Crux," that the bigger of a pair of stars seems to have lost heat quicker than the smaller one. The solution is simply that they were May and December when they wedded.

Not merely must differences of age, differences of mass, differences of density, give variety to impacts, but also differences of depths of graze. And here the principle is simple, the shallower the graze the more evanescent the new star. The greater the mass of the colliding suns, the greater the brilliancy. Again, the deeper the graze, the greater the chance of the union of the torn suns into double stars. The deeper the graze also, the smaller the orbit. Large proper motion acts in the opposite way to deep grazes; when more than a third is cut away from each of a pair of similar suns in parabolic orbits, they become coalesced into one body; thus possibly originated Wolf-

Rayet stars, and thus possibly originated our own Solar System.

The pair that formed *Beta Lyræ* did not cut off one-third of each, unless there were great original proper motion; but the cut that formed *Beta Lyræ* was fully a fourth part of each body. The meteoric swarm of that big third body is somewhere about or between the two torn suns; it must add to the complexities of the light-curve. *Beta Lyræ* may retain the remains of one or both of the scars that were left where they were torn; if so, it ought to give a permanently recurring bump on the light-curve. From the stars being so comparatively close, tidal action ought to have given both stars a period of rotation synchronous with their revolution.

It would seem that in every partial impact, axial extrusion must to some extent come into play, and probably reaches its maximum in cases of whirling coalescence.

Such an effect as axial extrusion would possibly tell most in the case of the interpenetration of such systems as the two Magellanic Clouds. Before the centres of gravity of two such systems approached their nearest point, the space between these points would almost certainly have been the site of many collisions; hence nebulous matter would be abundant. The onward progress of the suns would also be interfered with, and the road would be blocked by newly formed double stars.

That is to say, suns having had their onward motion converted by a partial impact into orbital motion, they would revolve where the impact occurred. A great number of writers, even those who do not believe generally in collisions of suns, believe they take place when bodies are retarded in a nebula. An instance of this action is given in my explanation of the concentration of variables in certain star clusters, and in special parts of some other star clusters.

Hence the space between the two centres of gravity of the pair of interpenetrating cosmic systems when near one another, would rapidly become the scene of innumerable impacts, and develop into a vast central furnace, similar to that still blazing in the nebula of Andromeda. The advanced spiral formation seen in pictures of that nebula suggests that the central furnace has nearly burnt itself out.

Should its density remain constant, this central furnace, as it increases in diameter, would increase its critical kinetol; it does so in proportion to the square of its radius. Hence soon every star that entered would, without collision, be volatilised by its mere plunge into and through the intensely hot nebula. This furnace will be walled in all around by the two advancing cosmic systems. Axially in both directions matter would be free to escape, some of it would be expelled; this ejected material would clothe the poles of the plane of the whirl

with matter. As it would be highly heated, atom-sorting would ensue; the heavy atoms would be chilled, and the light gases would escape from the coalescing systems. In these two ways, of pressure and selective escape, the density of the central portions of the furnace would be lessened; its attraction would lessen also; and its walls, and the stars outside, would be carried forward tangentially by their own velocity; thus the nebulous Milky Way and its stars would travel to enormous distances.

Whilst, on the one hand, by partial impact and the fusion in the central furnace of coalescing cosmic systems, suns would lessen mass and often be actually volatilised; on the other hand, all nebulæ would tend to entrap bodies. These, acting as condensing nuclei, would concentrate into single, double or multiple stars. Perchance some star clusters might possibly have been so formed. That suns do actually originate from nebulæ is proven by stars showing along the arms of spiral nebulæ.

In the interpenetration of two such systems, all the stars of each system that was on the other side of the centre of gravity of the other system, would have an orbital velocity in the opposite direction to that of the stars of the system itself. The double drift of the stars recently discovered is probably the residue of that motion. If so, we should expect that more stars would be going one way than the other. I am not aware whether such is known to be the case.

REVIEW OF THE ARGUMENT

Our Galactic System then is a contrasted one; a vast ring of stars, which by the crowding of vivid and dead suns, by their double drift, and by mutual attraction must produce solar impacts. In this ring or double spiral we should expect to find the wreckage left by star collisions, such as temporary, variable, double, and Wolf-Rayet stars, planetary nebulæ, and other gaseous nebulæ, showing bright line spectra. There also we should expect to find star clusters and nebulous stars. We, as a fact, do find all these bodies and systems where we should expect to find them. At the two poles of this ring we should expect globular, cometic, double, spindle, and spiral white nebulæ, giving continuous spectra; we find them there.

All previously existing motion in colliding systems tends, of course, to disturb this regularity; the Milky Way has great branching streams; such branches would be due to original lateral rotation, at an angle to the plane of the whirl of the collision.

All other irregularities are probably due to similar causes.

During the correction of the proofs of this book, I read in the "Observatory" (p. 463) that at the meeting of the Royal Astronomical Society, the President, Sir David Gill, called attention to the fact that "Prof. Kapteyn investigated the proper motions of the helium stars both in the neighbourhood of Scorpius and Perseus, and communicated

a paper on the subject to the American Solar Union? He has found the extraordinary fact that the helium stars in Perseus have proper motions in one direction, nearly in the plane of the Milky Way, and the helium stars in Scorpius have nearly equal but opposite motions in the same plane. He is now going on to see what are the proper motions of the helium stars in other regions of the heavens, to see if they suggest a relation of all these stars in the plane of the Milky Way."

I have sought for thirty years for information that star drift had a maximum resultant in the plane of the Milky Way. I hope, as Sir David Gill suggests, that further information will be forthcoming.

In our Solar System its order is the offspring of the grand original collision that welded the two systems. Its disorder is due to motions previously existing or to the motion of visitors from outer space that have been entrapped since the impact.

We have, in this volume of "Harper's Library of Living Thought," given a somewhat detailed study of Partial Impact, and its resultant, the Third Body. We have seen that this one event by its many agencies may produce temporary, variable, and double stars, meteoric swarms, star clusters, and planetary nebulæ. It may also disperse through space countless free molecules of light gas. We have given a preliminary glance at the forms of impact that develop agencies, which may have given rise to white nebulæ of all

forms, of the impact that may have originated our Solar System, and the Galactic System. We have treated in some detail the Universe, its birth, its development, and the mode of the rejuvenescence of such systems. We have also hinted at a most numerous and intricate series of agencies, that together tend to give us the possibilities of a cyclic cosmos. In this cycle are forces that tend to disperse as well as to concentrate matter; to elevate as well as to degrade energy. In a future volume I hope to give a full picture of cyclic cosmos without evidence of a beginning or promise of an end, an infinite and immortal scheme of creation; the whole so flawless as to dispel the pessimism induced by the expectation of eternal death, and capable of replacing this dismal doctrine by an absolutely logical optimistic philosophy. This view of life suggests that the remaining gift at the bottom of Pandora's Box, namely, Hope, will grow to be so powerful as to enable us to destroy the imps of evil she let loose. In a world so freed man will attain his true birth-right, a life of love and joy, in which all beneficial achievements are made glorious by the esteem and approval of his fellow-workers. We have now but to treat of the one all-important question;—Is the theory true? Does it correspond, as far as it goes, with the facts of nature? Is it a helpful contribution to living thought? When we have answered these questions, our present task is done.

CHAPTER XII

CONCLUSION:

THE TRUTH OF THE THEORY

PROBABLY there are but few, even amongst the most sceptical of my readers, could they only believe the basic parts to be true, but would agree with Professor Barrachi in thinking the theory of the third body to be fascinating. Some would even go as far as Lord Kelvin, when at different times he called it "a beautiful correlation," a "remarkable theory," and a "magnificent generalisation." Unfortunately, without the previous trouble of studying, there has spread a belief that no third body would be formed at all. This question of the third body is of course basic and all-important. I believe no one who has really studied the question, but must be convinced that, as colliding suns possess energy of molar motion equivalent to scores of millions of calories, and energies of unit mass or kinetols fully ten thousand times that of the swiftest Krupp shell, they must pass one another. Surely no student will believe such suns can possibly be arrested in their onward motion by a slight graze? If grazing suns go on past the point of collision, then it is dynamically

certain that the parts actually meeting must form a third body. I assume this deduction to be unquestionable. As already mentioned in the body of the book, this is the unanimous opinion of all the engineers who have studied the subject; the question is practically one of elementary mechanics.

What then are the objections left? All ever offered are absolutely unimportant as regards the broad generalisations. They are of two orders. First, actual dynamical blunders, such as adding two velocities to get the resultant. A type of thermodynamic error is the idea that, although the same velocity be destroyed in a case of partial impact, and complete impact of similar elements, yet the temperature of the third body cannot be the same as though the whole suns had collided. The most persistent kinetic errors are first, the idea that in partial impact the tremendous mutual attraction of the two suns will prevent their separating after they have come together; and secondly, the erroneous idea that the same tremendous attraction must cause them to collide completely instead of grazing. These dynamical blunders, and many similar ones, were made in New Zealand on the reading of my first papers. It is singular that these objections are often made in England, and sometimes even by eminent men. This class of objections is continually born again and again, even up to the present. But their life is generally

short; they are speedily slain by somebody present at the discussion, who knows something of dynamics. The other class of critics are those whose objections are sound, as far as the details they object to are concerned, but not sound where other interacting agencies are also considered.

A common example of this class of oversight, is connected with the orbit of double stars. It is the idea that, because the laws of the orbits of cosmic bodies tell us if a pair of stars in closed orbits once graze they must collide again, therefore double stars formed by partial impact must also do so. This of course would be true if nothing interfered; but in double stars it is the third body's attraction which first wedded them, and this body has largely dissipated itself before the stars commence their return journey towards one another. Hence they do not generally come near one another. The examples of this class of objection are many and various; most of those, like the orbit objection, have been disposed of long ago, and some of these are again answered in the pages of this book itself.

The other objections urged since I have been in London during the past few months, generally come under one of two classes. The first is, that we do not see a pair of variables where a *Nova* has been, or we did not see the *Nova* where variables are now. The other class is connected with the spectrograms of *Novæ*.

THE TRUTH OF THE THEORY

I have had to answer these two classes of objections a surprising number of times, both in Australia and in England: but because, in both of these opposite ends of the world, these erroneous objections have blocked the acceptance of the theory for many years, are doing so now, and promise to do so in the future, it is absolutely essential that they be once more answered. I shall give the favourable evidence on these points presently. We must now show the baselessness of the objections.

First let me apologise, and own that I now feel certain I was led astray by astronomers in their reading of the spectrograms. I thought I lacked the astrophysical training necessary to read them myself; hence I accepted the current explanation, which was that the black and bright bands represented two bodies flying in opposite directions. The fact that they could be so readily seen greatly surprised me; but still I felt I must accept the authoritative explanation that these bodies were the two torn suns. This I now believe to have been wrong. Mr. F. W. Frankland, the statistical mathematician, has been interested in the theory of the third body from the first, and has helped me a good deal, especially in sending me evidence. He sent me a copy of Newcomb's "Side Lights on Astronomy," with the passages that gave evidence marked. It contained a spectrogram of *Nova Aurigæ.* Directly I saw it, I felt sure that the old

reading was absolutely wrong. I could detect nothing in the spectrogram that suggested anything but analysed light from the nucleus of the central body, from its ensphering shells, and from the two ends of the spindle. What I think that spectrogram really means, is debated in the body of this book.

Returning to the reiterated objections, that have done and are still doing so much harm, our theory suggests that a temporary star and two variable stars are born at once, and that the two variable stars often become a double star. It is objected that I have not given examples of such connection. Yet the " Romance of the Heavens " absolutely teems with the most striking evidence of such associations; some of this and of the later evidence I will give presently, some I have already given earlier in this book. I suppose what my critics expect is, that new stars should always exhibit to our observation the suns that produced the *Nova*. It is as if, on a dark night, one expected always to see the stone that gives a spark when struck by a horse's shoe. Continually I emphasise the principle, that the greater part of the energy of motion converted into heat in grazing suns must be confined to the third body; but even that fact is of far less importance than the basic principles that the third body explodes, whilst the fiery lakes on the torn suns are, compared with that flash, like steadily burning lamps, lasting

perchance thousands of years. The bulk of the energy of the exploding body is generally used up in a few weeks. A ton of dynamite has not a tenth part of the energy of a ton of petrol. Detonate a ton of dynamite, and you have a sensational paragraph-producing pyrotechnic display; use up your ton of petrol in lamps continuously burning for a year or two, and no one says a word. Thus there are three reasons why we do not generally see the torn suns; they have only a small share of energy; they burn steadily instead of exploding; and they are often so far away that we can hardly see the *Nova*, much less see the variables. It is astonishing that we see variables as often as we do, rather than surprising that we do not always see them; for the maximum brilliancy of the new stars must generally be thousands of times that of the torn suns.

Then again, although new stars themselves are astonishing phenomena, they are not to us spectacular; the stars are so very far away; so far in fact, that in the past an immense majority have been altogether missed. The majority are not seen even now; we know of them by means of photography and the amazing power of our modern instruments. Clearly, therefore, it is not to be wondered at, that many examples of the temporary flash, which accompanies the formation of a pair of variables or of a double star, have not been often recorded. That any example should exist is

wonderful, if not conclusive, evidence. Doubtless the future will give us many examples, when the phenomenon is expected and looked for, but "when the mind is blind, the eye seldom sees." Much more might be said, but let this suffice until further criticism requires further answers. Now to the spectrographic objections.

Spectroscopy is probably the most complex and difficult of our modern studies. There are a number of salient, well-established principles, that have been already discussed to some extent, in explaining why an explosively hot cosmic body, made up of mixed elements, should produce the definite series of spectrograms described in this book. We see why the spectrum should at first be continuous, why next it should be crossed with black lines of hydrogen, why subsequently hydrogen should blaze out in broad bands, with shadows on their edges towards the violet end; why the shadow bands should disappear without lessening displacement, and why subsequently the blaze bands should disappear without losing width. All these points are characteristic of most *Novæ*, and are dependent on clear, sharp, and well-understood principles of spectroscopy. Yet even these are not generally understood in their application to *Novæ*. Of the mass of other complications there is hardly any end. A single element, namely, iron, produces thousands of lines, showing different rates of vibration; in other words, the vibrating

atom has thousands of overtones. These overtones are generally of a harmonic character; but elements have often several series, which may be of different orders. Helium, an element much in evidence in this book, has six series in two orders; three in each order. Then again, one element influences another, generally metals hide non-metals; hydrogen in this way tends to hide helium. Sometimes only a single series of an element appears in a spectrum; sometimes all the series of a single order. Pressure, temperature, electricity, magnetism, and density all influence the character of spectra; they differ as to whether they belong to a flame, a vacuum tube, an electric arc, or a spark jar. Broad lines hide narrow lines; lines coalesce and overlap; the radiation and absorption may equalise one another, and nothing appear. Overtones generally die down at different rates, and are differently produced. Atoms travelling in parallel directions do not hit one another, and so do not radiate.

Then again, studying the various spectra of the third body, we must in each case differentiate between the character of the spectrum of the ends of the spindle, and that of the central part. The two are deduced to give absolutely different spectra. We have also to think of the difference of the spectra of a *Nova* in a star cluster, and of one in the galaxy; these again are deduced to be quite different the one from the other.

It is obviously ridiculous to debate in so small a book all these conflicting forces, and other interacting agencies; they must be carefully studied as they offer themselves. Clearly the objector, who thinks he finds details that appear to conflict, should take into consideration all the above variations that are likely to be interacting.

Would it not be better for the present, to follow up and use the parts that are characteristic, that are demonstrated, and are easily understood, rather than wade into a mass of mutually interfering, and trivial complexities, that are quite unimportant? In the future when the theory is used as a working hypothesis, these data if studied with seeing mind, may unfold the mysteries of spectroscopy itself. Certainly, as Sir David Gill so ably puts it, "The stars are the crucibles of the Creator"; and of all the stars, new stars are the most prolific in wonderful revelations.

Having thus said a few words to those who are so sedulously barring progress, we will try to show how absolutely the basic parts of the generalisation have proven themselves by evidence to be true. I shall not here say a word of the strongly expressed opinions of great men, as to the certainty of these demonstrations, but simply show the evidence itself.

The fundamental conception is, that always a slight graze of suns will produce three bodies, and this whether the grazing pair be vivid stars or

dead suns, or one of each. One body, the new one, will be supremely and transitorily brilliant, and there will be two others, whose luminosity is unevenly increased, but in a comparatively slight and steady manner. The first must produce a temporary star with a special light-curve, that has always been found to absolutely and invariably correspond exactly with the light-curve theoretically deduced; yet this curve is quite inexplicable by any other existing theory. The two scarred suns may or may not show as variable stars.

The third body may often divide into a nucleus and ensphering shells of gas, which must generally produce the abnormal yet quite characteristic shaded blaze band spectrogram, that has actually enabled many new stars to be detected.

The molecules separate into three orders: those which escape by being above the critical velocity, those which may be attracted into a nucleus by the velocity being well below the critical, and thirdly, those whose velocity is approximately critical, or whose energy of rotation prevents coalescence. These atoms tend to produce meteoric swarms and planetary nebulæ with ensphering shells. We have seen also that the new third body tends to attract the two torn suns, and may wed them into a double star. Obviously, then, we expect to find variable stars sometimes in pairs, to find double stars more frequently variable than ordinary stars and sometimes doubly variable. We expect to

find both double and variable stars connected with nebulosity. We expect a planetary nebula to have a nebulous star, a double star, or a meteoric swarm at its centre, or a coalescence of any two of them. We should expect that where variable stars are, there may have been a recorded temporary star. Spectroscopic doubles being probably produced by deep grazes, we should expect evidence of variability apart from eclipsing effects. We should expect old and young stars to be wedded ; that is, dead suns and vivid stars to be in pairs.

We should expect all kinds of pairs to be occasionally associated with nebulæ. We should sometimes expect one of a pair, or both, to catch the meteoric swarm, and we should expect this swarm to assume an oscillatory orbit as it revolves around its captor, and to give it an appearance of nebulous haze. We should expect all and each of these peculiarities to sometimes show themselves, but we should hardly be justified in expecting such an amazing, such an absolutely convincing piece of evidence, as to find almost all of them in one example of a double star. Yet this is the extraordinary system we found last winter, whilst I was in Sydney. Mr. Nangle, F.R.A.S., President of the local branch of the British Astronomical Association, was working at the orbit of the double star Lacaille 2145. He could not get it right. I gave a lecture on "The Third Body," and happened to show how easily the two suns might divide the

meteoric swarm between them, or one or both of them capture it. Nangle came to me, and asked if I thought that was the cause of the double star's abnormal orbit. I studied it, and came to the conclusion that an entrapped swarm certainly might produce the effect. I heard that Mr. Tebbutt, F.R.A.S., had studied the star, and I wrote to him to inquire about variability, etc. Nangle, in the meantime, went on with his plotting, and found the idea of an entrapped swarm would overcome his difficulty. The letter I got from Tebbutt was extraordinary. He had been watching that star for years; he had found both constituents to be variable; they had been more so in the past. He found micrometric work difficult, as the stars were often hazy, as though they were surrounded with a nebula. Think of this rich pocket of nuggets of fact, this extraordinary mass of evidence cropping up without any labour, simply by using the theory of the third body as a working hypothesis. This one star alone contains the material for a complete demonstration; for on what other possible hypothesis could such a set of extraordinary coincidences occur? Something like it occurred to me in London ten years ago.

I had written a letter to Gore about the variability of double stars, and he wrote a long reply, that was not very favourable to my theory. But before he posted the letter, he made a careful

examination, and in a postscript actually gave me four double stars, which he had there and then found to be variable. Do not these two examples, the only ones that I know of, in which the theory has been used to guide research, suggest that when fully used it will be a veritable scientific divining rod, that will reveal the gold of knowledge in a way almost unthought of hitherto? Besides these two cases, that were thus sought for and found by others, are there any other coincidences? There is not one of the cases of association, that should by theory occur, but has been, in fact, found. Variable stars remain where a temporary star has been; variables are in pairs beyond all expectation of probability; the number of pairs found is continually increasing, yet a quarter of a century ago Beverley made a statistical estimate of their being due to chance. He used the chart we had plotted from Chambers' list. He found there was only one chance in 167 sextillions, that they were not connected by some law. What other law than partial impact has ever been suggested? At page 89 several pairs are given taken from the "Romance of the Heavens," and hundreds of variables have been found since its publication. Again, double stars are variable by the score; many are doubly variable. This is still more wonderful evidence than the pairing of variables. The association of both variables and double stars with nebulæ is said by astronomers to be

absolutely remarkable. As deduced, double stars are at the centre of planetary nebulæ, as are nebulous stars and meteoric swarms. Planetary nebulæ are formed, sphere in sphere, with the light gases outside, and the heavier inside, whilst often at the centre is a nebulous mass giving a continuous spectrum; two of these are described on page 121. Planetary nebulæ often have a symmetrical irregularity, as would be expected from the impact theory of their origin. All and every one of the classes of variable stars, which the ideas of volcanic torn suns suggest to exist, have been found. The idea of this volcanic lake of fire suggests uprushes of flaming gas, that should produce bright lines in the spectrum; it was accidentally noticed that such bright lines were common to the spectra of variables.

By looking for the blaze band of such an anticipated spectrum, hundreds of variable stars have been found by Mrs. Fleming, some of them being doubly variable double stars. Then again, these stars are thickly spread where we should expect them to be. All these objects, which we have deduced as being formed by star collisions, are in just such positions as we should look to find them. Variable, double, and Wolf-Rayet stars, star clusters and planetary nebulæ are thick in the Galaxy, and in the Magellanic Clouds, exactly where deduction tells us we should expect them to be. On the other hand, most of the white

nebulæ of exquisite forms, the spindle, spiral, double and cometic nebulæ, are at the galactic poles, just as we should also expect them to be.

All the characteristics of the regularity and irregularity of the Solar System grow up as deductions from the hypothesis of whirling coalescence. Whilst the double drift of the stars in the Galaxy suggests the remains of the opposite motion of the pair of oppositely-moving interpenetrating cosmic systems, from which it is suggested the Galaxy had its origin.

Can all of this evidence be but the accidents of blind chance, or is it the offspring of exquisite laws? The answer is obvious; it is the offspring of cosmic law and order. When we step from deductions capable of being demonstrated by observation, to those that are but mathematical deductions, we may perhaps doubt; these deductions, however, able mathematicians have deemed to be a *vera causa.* Shall we stand trembling in cold and dismal doubt, instead of believing in the rational probability of a cyclic cosmos?

When the great thinker, Lord Kelvin, propounded the apparently inexorable law of dissipation that he had discovered; when all the great philosophers and scientists that opposed this dismal doctrine of eternal death, that grew as a logical deduction from that theory, failed to find a flaw in the reasoning, and eternal death seemed the undoubted fate of all things; then pessimism was

perhaps allowable, if not inevitable. But if the entire mechanism of a cyclic scheme of creation be within our thinking power, surely we should use it as a basis of a rational optimistic philosophy of human life, out of which grows the faith that—

> Pain is God's message telling man he errs;
> Dire misery reveals deep social wrong;
> Joy is God's index unto righteousness.

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